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IRON + = RUST

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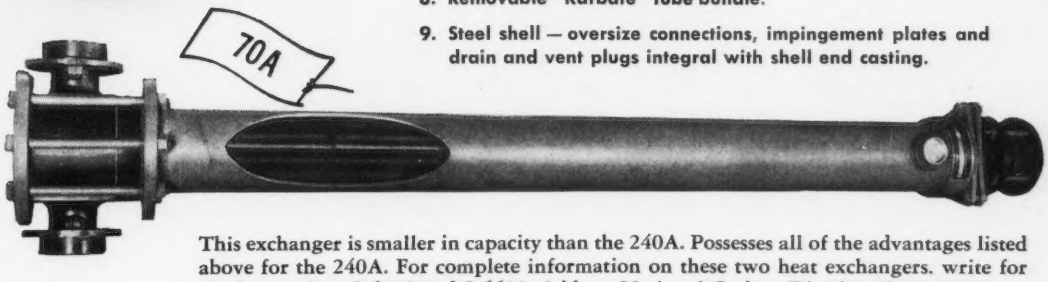

This exchanger is smaller in capacity than the 240A. Possesses all of the advantages listed above for the 240A. For complete information on these two heat exchangers. write for catalog sections S-6715 and S-6690. Address National Carbon Division, Dept. CO.

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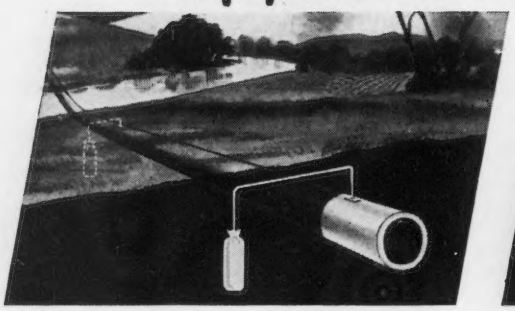
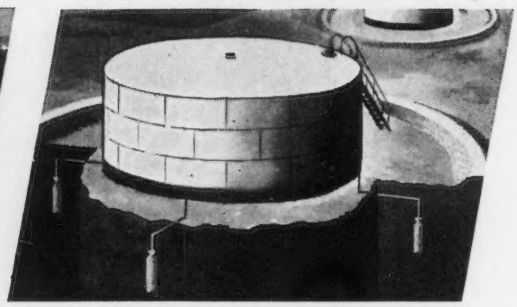
Dowell Magnesium Anodes Cut Corrosion Costs

on pipelines



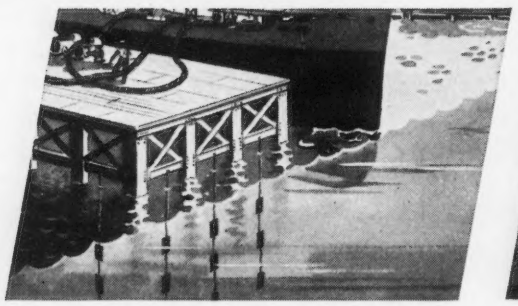
Thousands of miles of buried pipelines are being protected against corrosion at low cost by Dowell magnesium anodes. Such galvanic protection is proving equally effective on coated, wrapped and bare lines.

on tank bottoms



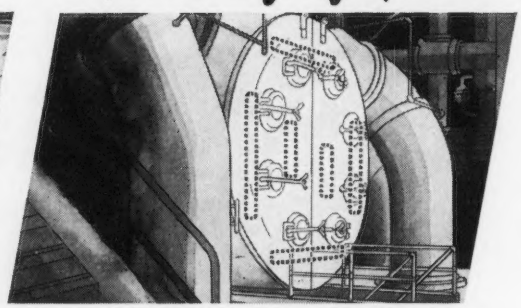
Many firms use Dowell magnesium anodes to prevent the corrosion of the bottoms of large storage tanks. This type of protection is also proving effective for oil lease tanks, gun barrels and completely buried tanks.

on sea water installations



Dowell magnesium anodes are proving satisfactory in controlling corrosion on steel piers, off-shore oil well drilling platforms, ship hulls and other underwater structures.

on operating equipment



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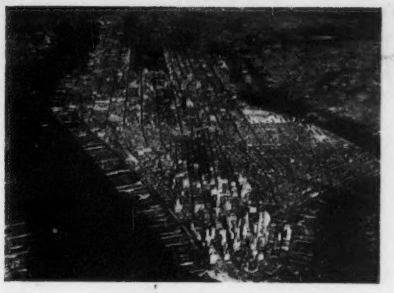

—*Fairchild Photo*

THIS MONTH'S COVER—This view of Manhattan Island and adjacent waters and boroughs looks northerly from the Battery toward Central Park which may be seen left of and above center. Persons familiar with this prodigious city may be able to identify many world-famous landmarks which will be seen by those attending the Seventh Annual NACE Conference and Exhibition, March 13-16.

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Approved for Publication in Corrosion:

CORROSION PROBLEMS IN THE MODERN BY-PRODUCT COKE PLANT
By E. A. TICE, The International Nickel Co., Inc., New York City, and C. F. POGACAR, The Mellon Institute, Pittsburgh, Pa.

WHAT MANAGEMENT EXPECTS FROM THE CORROSION ENGINEER
By JOHN J. JACOB, The Peoples Natural Gas Company, Pittsburgh, Pa.

We Offer . . .

the following services in Texas and Louisiana to help meet your corrosion problems.

I A GUARANTEED maintenance program on tanks and steel structures wherein a pre-determined cost extending over 9 or 12 years, averaging 4 cents per year, per square foot can be properly budgeted.

II TANK LINING service with fully proven protective linings for **Sour Crude, Acid Sludge, Run Down, Acid Storage, Caustic Storage and Floating Roof Tanks.**

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VII Complete LABORATORY advisory service at no obligation.

We invite your inquiry on corrosion problems. They will be given prompt and courteous attention.

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RUBBER LININGS

Rubber and Koroseal Linings for protection of tanks, pipe and fittings used in handling and storing corrosive chemicals. Linings applied in field or shop to tanks you are now using or new tanks fabricated and lined to your specifications. Licensed applicators of B. F. Goodrich products.

Other Metalweld Services include Metallizing, Welding, Sandblasting, Amercoat Plastic Coatings. Inquiries are invited. Write for Bulletin (R).

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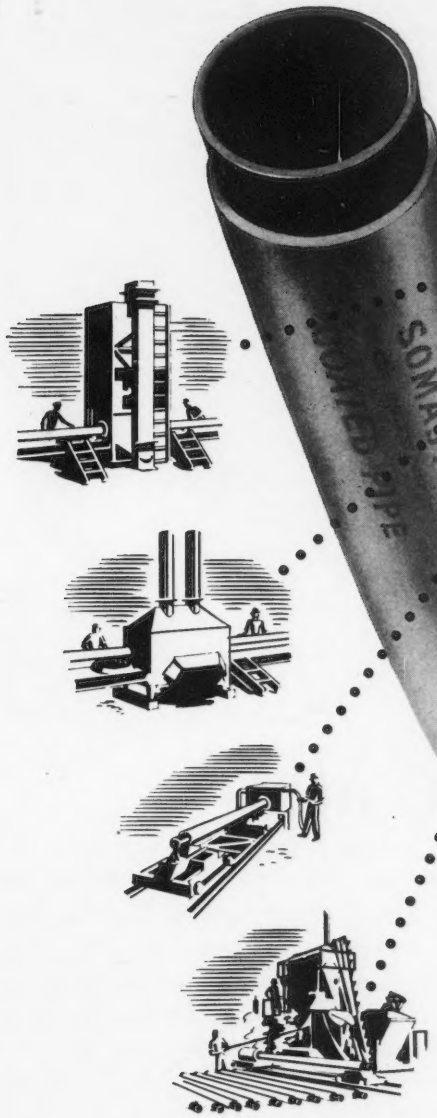
SOMASTIC* PERMANENCE

includes TIME TESTED METHODS of Application



For the past 20 years SOMASTIC PIPE COATING has been applied to pipe by standard practices which only now are being adopted generally by the pipe coating industry. Time has proved them most effective. These methods are—

★ *Thorough cleaning of metal by grit-blasting.*

★ *Pre-heating, followed by hot priming, assuring a firm, lasting bond of coating to steel.*

★ *Selection of materials and manufacture of coating to rigid specifications.*

In addition, SOMASTIC leads in this essential feature—

★ *Application of coating to primed pipe in a continuous process by special* SOMASTIC *equipment to form a dense, compact, uniform and seamless protective coating of great durability.*

The general swing to methods pioneered by SOMASTIC Pipe Coating is another acknowledgment of a fact first shown by the API-Bureau Of Standards Ten Year Pipe Coating Tests . . . and since proved at thousands of corrosive locations . . . for *permanence* coat with SOMASTIC.

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*Reg. U. S. Patent Office
PIPE COATING

Unequaled for PERMANENT PROTECTION

SOMASTIC IS The Best PIPE COATING

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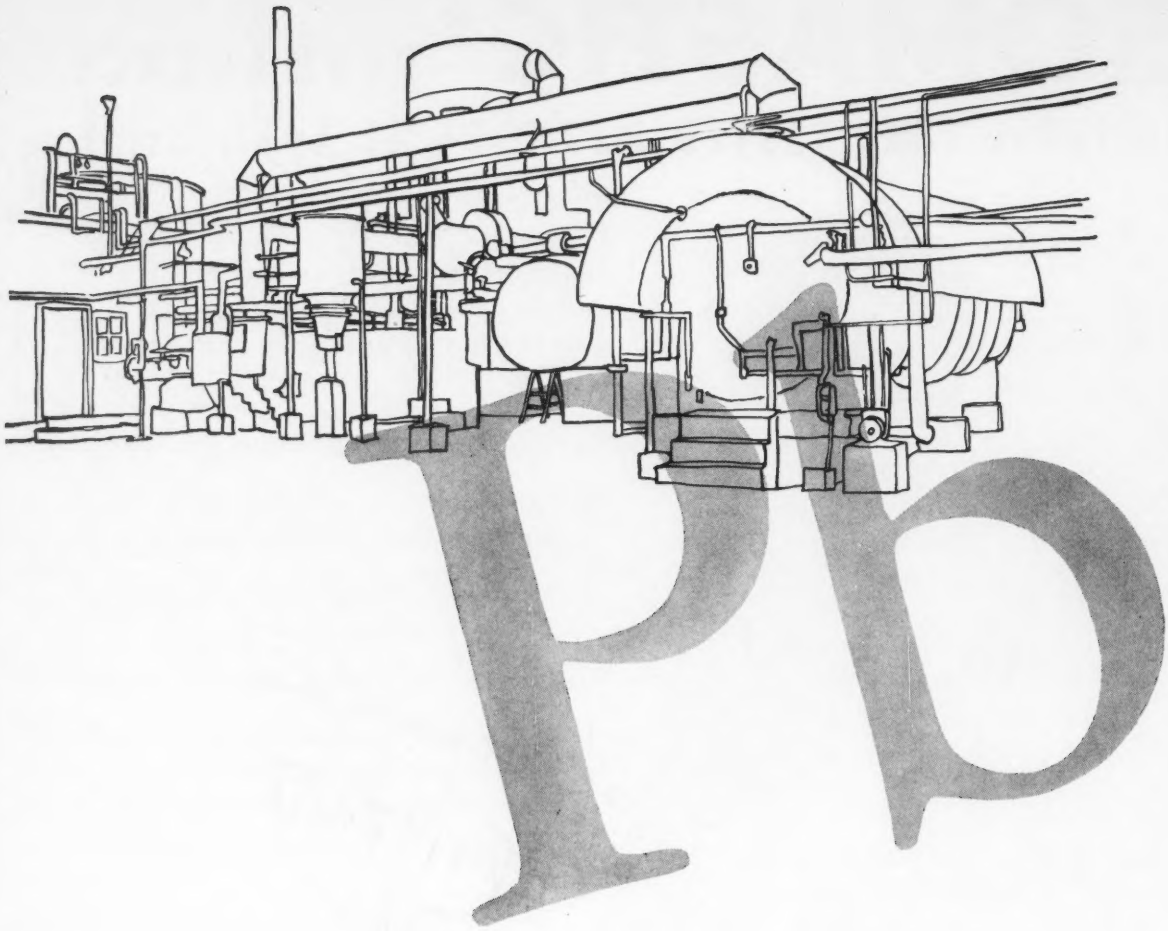

USING SULFURIC ACID?

Under many pressures, concentrations and temperatures, lead is the ideal material for handling sulfuric acid. It safely handles other corrosives as well.

For fabrication, lead is unique. Sheet lead can be welded, or "burned", to form a continuous lining; it can be bonded to another metal. Lead can be cast, die cast or pressure molded; extruded as pipe or other shapes; fastened by welding, flanging or bolting. Once installed, lead chemical equipment is easily repaired with a welding torch.

Because of the many complex factors in any corrosion problem, expert advice is usually advisable. For complete technical assistance, see Federated first. For lead products, think of ASARCO Brand lead pipe, lead sheet, and lead fittings.

Available in all standard sizes and forms through Federated's 22 sales offices across the country.

Federated Metals Division

Federated first in the non-ferrous field — FMD

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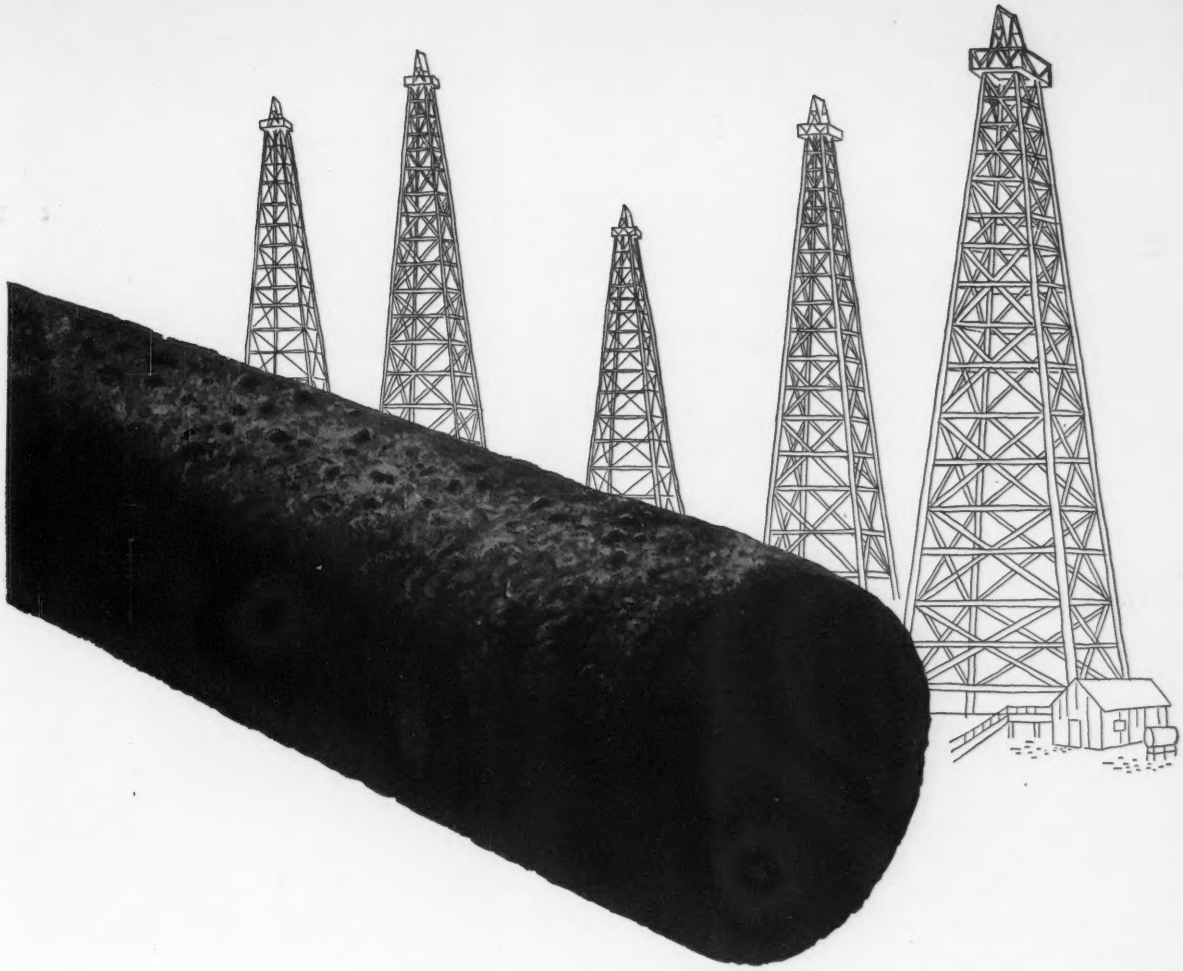

Here Are Some Facts On CORROSION INSURANCE

One of the most economical ways to insure storage tanks, pipelines and buried metal structures against the harmful effects of corrosion is to install Federated Magnesium Anodes.

The cost of Federated anodes is only a fraction of the cost of the losses preventable by their use. Deterioration of structures, loss of bulk materials handled, time, labor and materials to replace damaged equipment, can in many cases be avoided at very low cost by the use of magnesium anodes.

Federated Magnesium Anodes are a high quality product. Each has an electro-galvanized spiral-wound steel core chemically bonded to the magnesium alloy to permit perfect electrical contact between the metal of the anode and the metal to be protected.

Federated Magnesium Anodes are readily available in every standard size; special sizes can be made to order quickly. Technical assistance on corrosion problems is available at your request.

See Federated first for magnesium anodes . . . for any non-ferrous metal or alloy.

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Federated first in the non-ferrous field FMD

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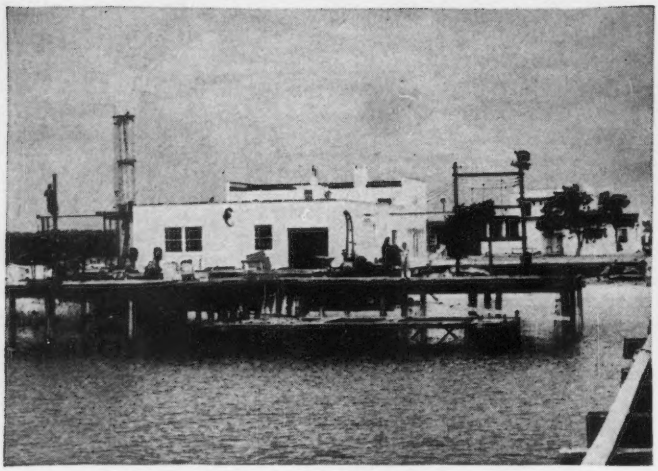


View of Harbor Island Laboratory and Testing Station.

New testing station provides expanded facilities for corrosion studies

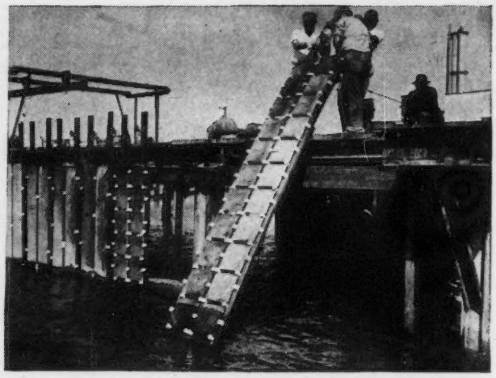
During the past 15 years, the Atlantic Ocean at Kure Beach served as a giant test tube for studying attacks of sea water and salt air upon more than 35,000 specimens, including virtually all types of metals and alloys.

Storm damage to the basin, in which the underwater tests were conducted, compelled establishment of a new and protected testing station. Accordingly, some 15 miles north, on Harbor Island, the new Inco Marine Laboratory was built to provide expanded facilities and an even better "Ocean Test Tube."

This new Harbor Island station, along with the atmospheric test racks retained on the shore of Kure Beach, now widen the scope of cooperative enterprise for fighting industry's common enemy — *corrosion.*

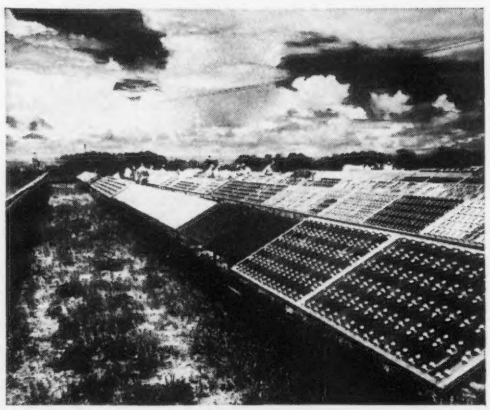
The vast amount of valuable data accumulated over the years will continue to be made available to all industry, as well as to government agencies for whom and with whose cooperation much of the research has been undertaken. You are invited to consult us on your corrosion problems.

EMBLEM OF INCO SERVICE



Lowering piling test specimens into place. Sea water is something more than a mixture of chemicals; its corrosive action over an extended period can be studied properly only by exposure of specimens to attack under natural conditions.

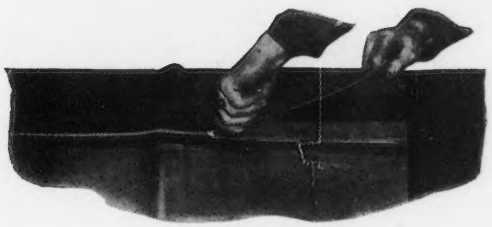
Running water troughs. For studying the action of sea water flowing at moderate velocities, specimens are immersed in the troughs, shown above. The total length of trough used for this purpose now amounts to about 600 feet.



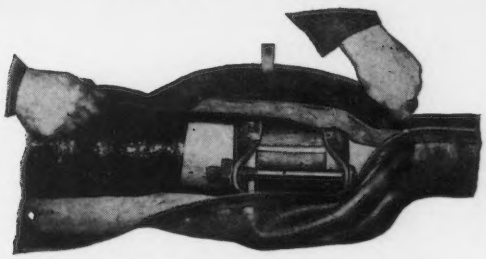
Atmospheric and spray test lot. Shown above is part of the atmospheric test lot at Kure Beach in which over 20,000 specimens have been exposed, some for over nine years. The racks face south, and the specimens, supported on porcelain insulators, are all set at a slope of 30 degrees.

THE INTERNATIONAL NICKEL COMPANY, INC. 67 WALL STREET NEW YORK 5, N. Y.

Now—you simply "pull the zipper" on corrosion problems



Dresser ZIPCOAT for welded joints zips over weld area, fits closely to the pipe. 30″ lengths.



Dresser ZIPCOAT for couplings is easy to install over joint and pipe ends—all in one quick operation. Has bleeder valve to vent air during backfilling.

Dresser ZIPCOAT for insulating joints is made like the ZIPCOAT for welds, but in ten-foot lengths. Installing one on each side of an insulating joint that's protected with a ZIPCOAT for couplings gives ultimate protection. Eliminates costly boxing and filling with dope. Immediate trench backfill saves time.

NEW DRESSER ZIPCOATS* GIVE SURE PROTECTION, SUPERLATIVE DIELECTRIC STRENGTH

"As easy as zipping up a jacket" is what workmen say about Dresser's new ZIPCOATS. They install ZIPCOATS in 1/10 of the time it takes to coat a joint. You get protection that equals or exceeds that offered by the mill or yard-wrapped pipe.

And look at the hazards you avoid: there's no flame; no heating, hauling or messy application of hot stuff; no danger from fumes or burns.

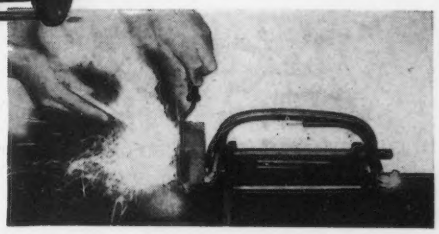
Can be installed in any weather.

Write today for descriptive material and price list.

*Every ZIPCOAT complete with anaerobic microbiological corrosion inhibitor and cold sealing compound. ZIPCOAT is a trade mark of Dresser Manufacturing Division.

Install Dresser Insulating Couplings **IN MINUTES**

Dresser Style 39 Insulating Couplings with new plastic gaskets insulate effectively and are the simplest insulating type joint to install. Sizes ¾″ to 30″ and up.



New Dresser Bonding Method saves up to 50% of cost; materials preformed

Fast bonding, giving low resistance with *pre*formed Dresser Bond and 5-second chemical welding method. Needs no special skill, no bulky equipment. Makes homogeneous weld area, eliminates surface contact variables. Compact kit of 50 *pre*formed bonds includes all materials needed for installing.

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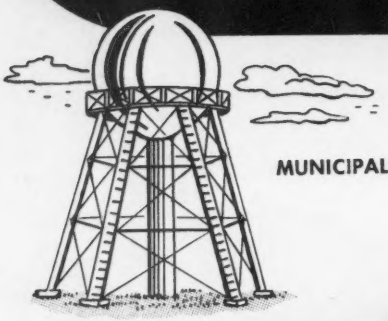
Headquarters: Bradford, Pa. (One of the Dresser Industries). Sales Offices: New York, Philadelphia, Chicago, Houston, San Francisco. In Canada: 629 Adelaide St., W., Toronto, Ontario.

STOP CORROSION AND RUST

NEW DEPENDABLE GOOD-ALL RECTIFIERS



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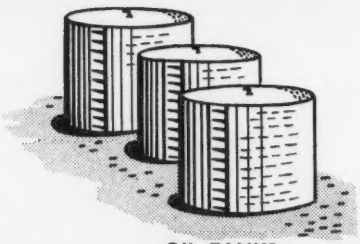
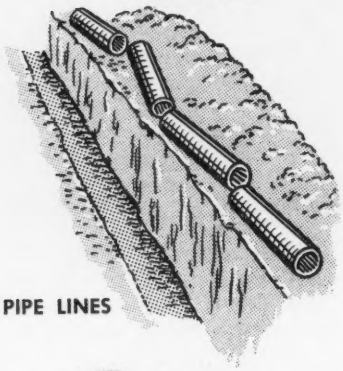


OIL TANKS

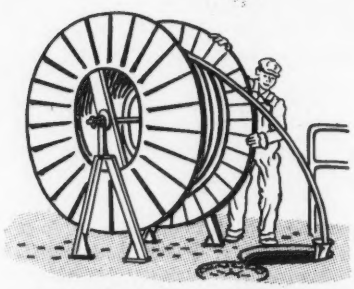
SELF COOLED – OIL IMMERSED



PIPE LINES

PERFORMANCE PROVES IT . . . THEY'RE MORE DEPENDABLE

GOOD-ALL Rectifiers are among the most efficient in service today! The engineering "know how" and quality materials used in building GOOD-ALL Rectifiers is your assurance of dependable, trouble-free performance under the most severe conditions. And they are built to last—many units have been in operation over 13 years and are still in A-1 condition. You'll find GOOD-ALL Rectifiers the best Cathodic protection for all corrosion needs.



UNDERGROUND CABLES

IN ADDITION TO OUR STANDARD MODELS

THE NEW "ADD-A-STACK RECTIFIERS"

Add One, Two, Three, Total of Four Stacks
Also models with Hermetically Sealed Stacks

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Please send me Complete Information on Rectifiers Checked Below:

SELF COOLED — OIL IMMERSED
"ADD-A-STACK" — HERMETIC SEALED

Name .....
Company .....
Address .....
City .....
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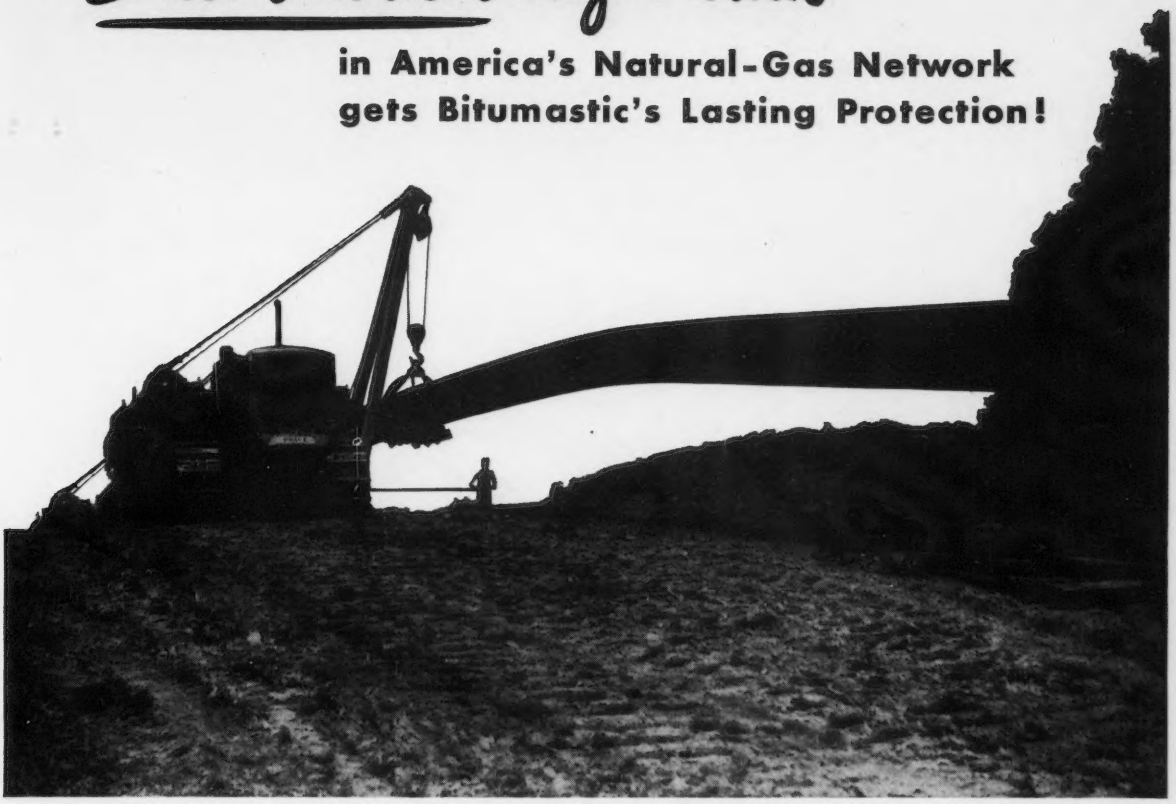
Still another major link

in America's Natural-Gas Network gets Bitumastic's Lasting Protection!



Koppers Bitumastic XXH Enamel being machine-applied

● The southern end of the Tennessee Gas Transmission Company's new line from Kentucky to Buffalo is protected against corrosion by Koppers Bitumastic® XXH Enamel. This extension consists of 373 miles of 26" pipe.

Koppers Bitumastic Enamels have established enviable records in combating corrosion. Under the most severe corrosive conditions . . . in all types of soil . . . under wide variations of temperature—pipe lines protected by Koppers Coatings have been giving good service for twenty and thirty years. And the experience gained by Koppers engineers in protecting these lines can be helpful to you.

Specify "Koppers Bitumastic Enamel" for your next pipe-line project. You'll be getting a protective coating that has been proved by performance. Your Koppers representative will give you complete details and estimates.

Why Bitumastic Enamels give lasting protection

Processed from a base of coal-tar pitch, they are impervious to moisture . . . chemically resistant to soil elements. They make a tight bond with the pipe . . . do not disintegrate with age . . . maintain continuously high electrical resistance.

KOPPERS BITUMASTIC ENAMELS

REG. U.S. PAT. OFF.

KOPPERS COMPANY, INC., Tar Products Division, Dept. 204T, Pittsburgh 19, Pa.

COROMAT

The new Parallel Reinforced Coromat underground pipe wrap made by Owens-Corning Fiberglas, completely eliminates breakage under normal field conditions. Tough fiberglas yarns are laid parallel with the length of the wrap putting the strength where the strain is greatest. Consistent quality, heat and moisture resistant, rolls of 75, 400, 800, 1000, and 1200 foot lengths available. Now, because of the new parallel yarns, the longest rolls can be used at high wrapping speeds without breakage. Specify Owens-Corning Fiberglas Parallel Reinforced Coromat in your mill and yard work as well as your "over the ditch" jobs.

GLASFAB

Manufactured by the Lexington Supply Company, GLASFAB, the new hydrocarbon thermoplastic impregnate Fiberglas cloth is impervious to moisture and heat and has a high tensile strength of 92 lbs. per inch. Soft, pliable and non-irritating to the hands, GLASFAB is widely used for hand-wrapping "hot spots," field joints, field repairs and for machine wrapping river crossings and "hot lines." GLASFAB is supplied in continuous rolls of 75, 400, 800 and 1000 ft. lengths.

KAPCO ROCK SHIELD

KAPCO Rock Shield, a protective shield for pipe and pipe coating has been subjected to vigorous tests under all operational conditions. Dense limestone rocks of varying sizes have been dropped from a height of five feet directly on the shield and still the electronic detector showed no holidays in the coating. This protective shield eliminates the need for padding the ditch under rocky conditions and has also been used with a high degree of success at river and road crossings, padding under river weights, pipe anchors and elsewhere where the coating is subject to damage in handling. Contractors of large pipe line companies all over the U. S. are specifying KAPCO Rock Shield for the "rough going." Rock Shield is available for early delivery in a Midwestern package which includes strapping, ratchet strapping tool, and seals.

* Manufactured exclusively by Keystone Asphalt Products, Chicago, Ill., Division of American-Marietta Co.

For prompt delivery Midwestern maintains warehouse stocks in Tulsa, Oklahoma City, Kansas City and Newark, Ohio

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NEW COREXIT

a corrosion inhibitor that saves you money, time and trouble.

Corexit is the answer to sucker-rod breaks due to hydrogen embrittlement and tubing failures due to corrosion. Injected or dumped into the annulus of the well, it builds up a protective coating inside the tubing and on the sucker-rod, checks corrosion already started and minimizes new corrosion. In addition, the oil you get from wells in which Corexit is used is generally much cleaner and the pipe doesn't become crudded-up with heavy material.

Send for this booklet, and late information on Corexit tests in sour crude wells.

Address Sales Technical Service
Humble Oil & Refining Company
P. O. Box 2180 Houston, Texas

HUMBLE

HUMBLE OIL & REFINING COMPANY

THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of membership, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers and elected directors are nominated by a nominating committee in accordance with the articles of organization. Election is by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 919 Milam Building, 803 Texas Avenue, Houston 2, Texas.

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Consolidated Edison Co. of New York, Inc., New York, N. Y.

Representing Corporate Membership

V. V. MALCOM.....1950-53
The Philip Carey Mfg. Co., Cincinnati, Ohio

D. C. GLASS.....1949-52
Pure Oil Company, Chicago, Ill.

E. D. VERINK, JR.....1949-52
Aluminum Co. of America, New Kensington, Pa.

WARD R. MYERS.....1949-51
E. I. duPont de Nemours & Co., Inc., Wilmington, Del.

D. E. STEARNS.....1948-51
The D. E. Stearns Co., Shreveport, La.

Representing Regional Divisions

FRANK L. WHITNEY, JR..(North Central) 1950-53
Monsanto Chemical Co., St. Louis, Mo.

ROBERT H. LYNCH.....(North East) 1951
Keystone Pipe Line Co., Philadelphia, Pa.

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Objectives of Technical Practices Committee 3– *Anodes for Impressed Currents*

By DONALD H. BOND*

TECHNICAL PRACTICES Committee No. 3 was originally begun as a private undertaking on the part of representatives from five different companies who held their first meeting in Shreveport, Louisiana, on January 31, 1947. Shortly after this meeting the National Association of Corrosion Engineers was asked to take over the sponsorship of this group and set it up as one of their technical committees. The Association honored this request and since that time the committee has functioned as a part of the national organization.

Objectives

The basic objective of committee TP-3 has to do with a study of materials which may be used as ground anodes in connection with cathodic protection systems where direct current from some external source is impressed on the circuit. In addition the studies are to include various materials which may be used as backfill material around the various anodes under study. Here it may be well to emphasize that the work of this committee is distinctly different from that being performed by the Galvanic Anode committee.

Scope of Work

The committee engages in the research and study as well as the actual field testing of materials as mentioned in the foregoing paragraph. Data studied by the committee are obtained from field tests made by cooperating companies. Such data consist of periodic readings taken at specified intervals by engineers of these companies. These field tests are designed to determine the effect of current density on the various anode materials and also to determine the efficiency of various backfills and chemical treatment of backfill material for the anodes.

Activities

Tests have been and are being conducted by this committee on steel, carbon and graphite anodes. Backfills being studied include natural soil, graphite, coke breeze, graphite and lime, and coke breeze and lime. Initially seven companies made installations in cooperation with the committee. Out of these installations one produced no results because operating conditions forced abandonment of the test. All other current tests have been completed except one which is located in the vicinity of Jackson, Mississippi. Tests at the latter site are expected to be completed during the first part of 1951.

The first interim report on work performed by this committee was published under date of March 1, 1950, and is known as Publication No. 50-1 of the National Association of Corrosion Engineers, with the title, "Ground Anode Tests on Anodes for Impressed Currents." It is planned that the balance of the work on current tests will be incorporated in a single report and probably released toward the end of 1951.

Tests performed so far represent one phase of the committee's program. Present plans provide for further studies of various field installations to obtain additional information in addition to what is already being secured. In these activities the committee will again welcome the cooperation of any individuals or companies who are interested in the subject.

Current members of the committee are as follows:

Chairman: Donald H. Bond, The Texas Pipe Line Company, P. O. Box 2332, Houston 1, Texas.

Members:

W. A. Broome—Arkansas-Louisiana Gas Company, Slattery Building, Shreveport, Louisiana.
Lee N. Spinks—United Gas Pipe Line Company, Box 1407, Shreveport, Louisiana.
W. W. Palmquist—National Carbon Company, Cleveland 1, Ohio.
J. P. Oliver—National Carbon Company, Cleveland 1, Ohio.
O. C. Roddey—Interstate Natural Gas Company, Box 1482, Monroe, Louisiana.
Derk Holsteyn—Shell Oil Company, Inc., Refinery, Box 2527, Houston, Texas.
Karl S. Hagius—Colorado Interestate Gas Company, Box 1087, Colorado Springs, Colorado.
A. W. Peabody—Ebasco Services, 2 Rector Street, New York 6, N. Y.
Frank A. Young—Susquehanna Pipe Line Company, 1608 Walnut Street, Philadelphia 3, Pennsylvania.
M. A. Judah—National Association of Corrosion Engineers, 919 Milam Building, Houston 2, Texas.
H. A. Knudsen—East Bay Municipal Utility District, Oakland 4, California.
H. E. James—Mississippi Power & Light Company, Jackson, Mississippi.

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Ohio River Division Corrosion Problems★

By J. A. DAVENPORT

IN CONTRAST with the wide range of testing, full scale, on marine structures and vessels, and on machinery and structures located in or handling treated fresh waters on inland rivers, long term tests concerning the corrosion factor of surface waters are relatively few. A number of tests of typical situations are operated by the Corps of Engineers and also by the Panama Canal.

The so-called fresh water tests are in media which can be grouped into two general classes. The first is the approximately neutral surface water found in much of the country, as represented by tests located in the Nashville and Portland Engineer Districts, the Districts of the Upper Mississipi Valley Division, and by the Panama Canal. The second group comprises waters polluted with mine, industrial and high oxygen-consuming wastes. Such tests have been located in the Pittsburgh, Huntington and Louisville Districts. Problems of abrasion and erosion as well as corrosion are common to both classes.

Advocates of no corrosion protection are well represented in the Corps, although the general practice is to give protection by painting, and in the tests in connection therewith, a number of the leading firms of the country are cooperating. Consideration of cathodic protection of metal, either as primary protection or as an adjunct to protective coatings, has been in progress for some years and recently some more-or-less primitive tests of this class of protection have been started, but methods and procedures are still in the development stages. Included in the no-protective-coating systems are the use of special alloys of iron and also non-ferrous metal materials.

The Corps of Engineers of the United States Army is an organization whose civil activities cover most of the country. Its administration is decentralized into divisions and those into districts for efficient operation. One of these divisions covers the area which is the drainage basin of the Ohio River and its tributaries. It is known as the Ohio River Division, and it is certain activities of this division which are now under consideration.

Division's Duties Given

The principal duties of the Ohio River Division are the construction, maintenance and operation of river channels, locks, dams and local protection projects, for navigation, flood control and allied activities plus several hydroelectric power projects. The present value of these projects is over one-half billion dollars. Annual construction averages over 10 percent of this figure. Allotments for construction and operation in 1950 total $90,000,000. The operation and maintenance fund is kept as low as possible, the operators usually having the feeling that they are pinched. Maintenance costs are under continuous scrutiny. An appreciable proportion of the structures and plant are constructed of corrodible materials, so the appropriate action, concerning corrosion, for each set of conditions must be determined at least once.

A consideration of the question of advisability of protection against corrosion may appear quite elementary to those who spend a great deal of time, money, and effort on such activities. Nevertheless, the question of the value of the efforts against corrosion is worked out directly or inferentially whenever anti-corrosion methods are put into effect. The question is open and recurring for each case. In this article some of the tests for corrosion protection in the Ohio River Division are discussed.

Timber, masonry, and earthwork structures ordinarily have low obsolescence and long inherent life. Metal parts of dams and locks and floating plant are subject to the wear of usage, to obsolescence and to corrosion, abrasion, erosion and change in appearance. Engineer structures are basically functional but some thought and money are devoted to architectural values.

Painting of structures for appearance is performed as a matter of course. Navigation structures have certain markers and colors according to regulations adopted for functional use, and craft are colored in conformity with established regulations. Painting of machinery is sometimes for use, for better visibility and working conditions, and for appearance. Because the work is primarily with water, relative high humidity is a continuous problem. Some of the metal equipment is under occasional or continuous submergence. Defensive methods involving corrosion-

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His work on development and design of the flood protection pumping program, and with river and dam structures in general, has included studies on corrosion defense along the lines of special metals, painting, and cathodic protection.

He is a NACE member.

Abstract

The organization and duties of the Ohio River Division, Corps of Engineers, U. S. Army is briefly discussed. The locations of tests conducted in recent years is given as well as corrosion studies underway and in contemplation. Cooperative studies and tests on stainless steels, low alloy steels, carbon steels and aluminum have been conducted. Results of different types of painting tests including varnishes and vinyls are outlined. Surface preparation necessary before application of the coatings and corrosion caused by atmospheric exposure is reported. Some interesting tests of the past decade are narrated and a summary of cost figures given.

resisting materials may result in aggravated galvanic action on anodic portions, resulting in the requirement of even further metallic protection.

Tests Were Started in 1935

The Ohio Division has been corrosion and abrasion conscious ever since its organization in 1933. Some cocperative abrasion tests were started in 1935 but partly through lack of interest by the field forces, no results were obtained. Later, painting tests were started in the Pittsburgh, Huntington, Louisville, and Nashville Districts. Pittsburgh and Louisville programs are under continuing observations, with some underwater panels now in their eleventh year of life. Other noteworthy Corps of Engineer tests are carried on by the Upper Mississippi Valley Division with headquarters at St. Louis, and in the Portland, Oregon, District. The activities centering in St. Louis and Rock Island, Illinois, are the most extensive tests within the Corps of Engineers. Other important tests are conducted at the Panama Canal.

Testing has to be considered in quite a broad way. Operationally, the question is: "Will a certain system under field conditions and field application perform as they have done in carefully organized tests?" Two examples should suffice to illustrate the difficulties of purely scientific interpretation of results: In one reservoir seven water samples were taken in different locations and depths all in one day, and then the procedure was repeated six months later. In the first set the pH range was from 3.45 to 4.07 and the specific resistivity was from 2050 to 2740 ohms per cc. In the second set the range was from 2.75 to 3.11 and from 735 to 1620. In general, in paint tests it is practically impossible to obtain identical conditions. Variations occur in type of surface, method of preparation, method of application, the individual applicators, and temperature, humidity, sunlight, and drying time.

Bulletins Are Issued by the Corps

Late in 1949, Engineer Corps bulletins on corrosion mitigation and protective coatings were issued. These bulletins were based on extensive research and experience by the Corps and upon recent reports of other agencies. Two recommendations are of special interest. For materials submerged for as much as two weeks at one time, submerged type of protection is directed. Where a portion of a structure is classed as submerged, the whole structure is to be so treated. In the Temporary Manual of the Corps of Engineering on Painting, dated 12 March 1947, six paints of phenolic resin vehicle type are specified for submerged areas. These are in the systems Types I to VI, inclusive. In addition, for small parts not exposed to sunlight or severe abrasion, and readily accessible for maintenance, cold applied coal tar is permissible. These systems have all had favorable tests by the Corps, three of the systems having been tested on the Ohio River and the remainder on both the Mississippi and Ohio Rivers, for periods up to eleven years. As discussed later, it is believed that these specially resistant paints will be found economically justifiable for metalwork which is classified only as in atmospheric exposure. The manual also includes a considerable number of federal specification paints. Corps of Engineers' guide specifications for painting, now in preparation, in addition to a considerable number of references to federal specification paints, will probably contain specifications on at least eight of the phenolic varnish paints and several of vinyl resin type.

Experts in the industries have been consulted for technical data on series 300's and 400's steels, the copper-nickels and aluminum. Various steel companies have joined in cooperative field tests of iron alloys.

Performance of Steel Studied

Performance of steels in inland water is under study by C. P. Larrabee, of Carnegie-Illinois. For low pH waters containing mining wastes, which occur in Ohio, Pennsylvania and West Virginia he indicates the suitability of stainless steel. Our experience has indicated that if some stainless steels are used, the remaining exposed surfaces should be similar or have adequate protection of some kind. Larrabee believes that for very corrosive waters. Steel No. 347 is not required, Steels No. 302 and 304 having given good performance. Also that while Steels 405, 410 and 430 do not perform quite as well, they may be satisfactory in resistance to corrosion.

Other tests on stainless, low-alloy, and carbon steels are in progress in the Allegheny (coal mine wastes), Monongahela (mill, industrial, and coal mine wastes) and upper Mississippi (typical) rivers. The stainless steels have performances similar to those just noted, with Steel No. 410 showing slight pitting in Allegheny only.

Of the commercial low alloy steels tested, Cor-Ten alone showed any superiority. An apparent anomaly is the improved performance of both Cor-Ten and structural when welded together in the Monongahela tests. In the alloy steel group, the only outstanding material is a recently patented chromium-titanium grade of steel which out-performed all others in every test. It is understood this grade has not been produced in other than development lots and, consequently, is not commercially available at this time.

Relative Losses Are Listed

Of interest to users of the rivers are the relative corrosion losses for structural steel. In the Monongahela the average weight loss was 0.75 pound per square foot specimen over a 2-year test period, and 0.020 inch average maximum pit depth; in the Allegheny 0.60 pound and 0.033 inch average maximum pit and in the Mississippi 0.227 pound and 0.012 inch average maximum pit. If the Mississippi is a typical example, the upper Ohio special corrosion problems may be visualized. At the easy end of this Division's problems steel barge life of over 20 years is obtained in the Tennessee River without any protection whatever.

Other cooperative tests are by International Nickel and Aluminum Company of America. The aluminum test is, to date, of two years' duration, and is interesting because of its indication of both corrosion-resistant and erosion-resistant qualities. This test is on the down-stream leaf of a bear trap where con-

ditions range from exposure to sunlight and very moist air, through thin films of falling water, to water at twenty feet per second velocity and carrying silt and gravel. Bear traps will be described later. They are the toughest testing positions in the river.

Whether to use any protection against corrosion is an involved problem in some cases, of which Ohio River bear traps are an example. A bear trap is an adjustable valve, dam, or gate. It consists of an upstream, called upper and a downstream, called lower leaf, both leaves being hinged at their outer edges. In the "down" position the upper leaf lies over the lower leaf. The upper leaf, as made, is a steel frame filled with heavy timber to form a water and air tight sheet. The lower leaf is all steel. In the raised position the upper leaf rests on the lower leaf, theoretically two inclined plates, one resting against the other at their upper edges. Seals at each side rest against the piers so an air or water tight pocket is formed. By introducing air, or water under differential hydraulic head, the leaves are lifted or unfolded to bring the damming edge to the desired height. In practice the metal (steel) face of the lower leaf is not protected and the metal is subject to both corrosion and abrasion from the water and the solids in the water, together with wear and corrosion from impact of falling water. It has been the belief of management that there is no justifiable protection method for this metal.

Reasoning in the "not-to-protect" school as applied to bear traps follows two lines. The first is that the metal rusts and forms a coat and cushion protecting the remaining underlying metal. Since, on examination, the metal may be pretty heavily coated with rust, this is true to a great extent. The second is that no surface protection could remain in place since rivet heads are worn away and steel plates are cut through, which latter results in destruction of the sealed air pocket. For those locations where plate perforation occurs, certainly the first condition of protection is not effective. Three questions applicable to these conditions are noted:

> First: To what extent will the stream abrade the metal, where corrosion is prevented by polarization?
> Second: What losses will occur if the rate of corrosion is only diminished by an applied current, if such condition is achieved?
> Third: An involved question of materials, methods, life and costs, on the schemes to paint the surface or apply metal coating. To date appearance has never been a consideration, but if surface color in keeping with other dam structures can be developed, this should be an additional credit.

Various Metals Being Tested

Experiments on protection of bear traps to date have not fallen into any fixed pattern. Alcoa has some carefully insulated aluminum plates on the face of one trap. After two years, the plates appeared remarkably free from any metal loss. Two plates have been removed for laboratory study, but no actual data has been released as of this writing.

No experiments have been made with 18-8 type of metal. At one dam in Pennsylvania, a large exposure of 18-8 acted adversely on the remaining ferrous metal and it is believed that the possibility of any electrolysis of this nature should be avoided in tests involving important structures.

A use for the low-alloy steels of the Cor-Ten type may be developed since the coupling effect with carbon steels may not produce injurious results. Some years ago, Yoloy, in an isolated installation (the discharge line of a dredge), indicated good wearing qualities. It was rejected because the operators did not want so wear-resistant a material.

Commercial zinc slabs have been bolted to two smaller steel plates in one experimental dam. No data is yet available.

Magnesium Anode Tests Interrupted

Two tests of magnesium anodes on bear traps have been lost by river action. One was set up as a full scale installation, with two anodes attached directly to the dam in pipe-cases welded to the face and also a bundle of anodes was placed in water adjacent to the trap and connected by wire thereto. This was to be an unorthodox test with amperage of about 150 microamperes per square foot average, for a face-area of 91 feet horizontal by 35 feet on the slope, with conditions ranging from complete submersion to upper half of leaf out of water. The water has a resistance approximating 2600 ohms per cubic centimeter. The overall average resistance would actually vary because the distance to anode ranged from 20 to 105 feet and also would be changed in the two areas around the attached anodes. Readings indicated that the expected current was flowing. After about 18 months the cages on the face were knocked off and the other anodes were lost. The questions which were to be explored in this trial were:

> "Since some rusting may be of an overall benefit, what will occur if the surface is not completely polarized, but the differential of potential is decreased?"
> "Will some areas become polarized and if so will there be any progressive polarization?"
> "If the rate of corrosion is lessened, will the rate of erosion or abrasion be lessened?" And these all sum up to the final one, "Will the interval between repairs be increased appreciably?"

On such a test as the one just described the futility of attempting to obtain laboratory type data is pretty evident, although current readings and weight losses were being recorded. Decisive results, in such instances, may be an evident general improvement of the observable conditions, but the final proof can be found only in an actual lengthening of interval between repairs, except that where a coating is applied, it can be assumed that the length of time, for which the coating lasts, can be a good measurement of its contribution to trap life. However, some general determinations on the value of any cathodic system of this kind can be made, based on electric current and voltage studies.

Test May Be Arranged

The other cathodic test was a co-operative venture with Alcoa. This was a straight test, based on accepted values for magnesium anodes, and along the lines considered by the committee on cathodic protection in water, at the 1949 NACE meeting. That committee has now probably agreed upon some definite procedure, and if so, a test using one of our installations might be arranged. Tests have not yet

been made of metallized surfaces but the observed results, on the aluminum plates, indicate good possibilities for Alclad or zinc coated plates. However, if parts of a face only are so protected, the cathodic action with adjacent bare steel should be taken into consideration.

Applied current cathodic protection with carbon-type electrodes is authorized for test on a bear trap, and will be installed as soon as conditions permit. This is to be along lines which were considered in NACE 1949 committee relative to tests on cathodic protection of pipe lines. This test will involve high-side current values, as contrasted with the low-side values, of the interrupted anode test. The installation will consist of lines of anodes placed across and on the steel face of the lower leaf. These will be in steel pockets and be surrounded by wood. Sufficient current and voltage will be applied to effect polarization, after which current and voltage may be varied for observation of conditions under low potential.

The chrome and chrome nickel metals have been mentioned only in a negative way. In one highly acid water location, studies were made for installation of applied current. However, as a practical solution all exposed metal in installations where it is considered necessary to use large areas of corrosion resisting metal are clad. For such cases the services of an experienced consultant should be secured.

Metallizing has not been tested successfully in this work. An important point emerging from one unfavorable test is that, if something new is to be tried, the advice of the best qualified authorities on the subject should be secured, rather than the opinion of production men, as to anticipated performance.

Tests of anodic type coatings may be made in conjunction with paint tests on bear traps. Also, if obtainable, hot-dip galvanized and aluminum-coated plates may be tried. In metal-coating on bear traps it will be necessary to have the remainder of the area coated at least with paint to prevent excessive loss of metal to unprotected areas because of natural galvanic action. However, under such an arrangement, the paint performance itself would be changed since the steel surface under the paint would be cathodic to the metal-coated carbon steel plates used in bear traps.

Long-Term Program Under Way

The present paint testing program is now in its twelfth year. In general, for hydraulic structures, the quicker-drying synthetic resin varnishes have been found more satisfactory than linseed oil paints. During the period one district found a biennial repainting over old paint by lock forces a cheap maintenance plan when the structures became available from other conditions. However, varnishes are used now. Present paint testing is concentrated in Pittsburgh and Louisville.

Coal tar paints have been under test and in use for many years, sometimes with unusually good results. Although some installations under favorable conditions have had 20 years of life, they are generally used only where they can be readily repaired if damaged. For conduit linings the spun coatings are highly regarded. Asphalt linings for pipe inverts are used also. No tests of any of these have been made up to this time.

The paint test panels with over 10 years of life in the Pittsburgh and Louisville Districts have several things in common. While of several pigment combinations, they are phenolic-resin oil varnishes, all containing tung oil. They were all repaint jobs, the surfaces being carefully prepared, and application more carefully done than could be expected from maintenance field forces. A phosphoric acid type pretreatment made a favorable showing. Aluminum pigmented paints have proved satisfactory over several types of prime coats. Zinc dust-zinc oxide, sometimes in combination with titanium barium or iron oxide, and several red lead and white lead combinations are in the top rank. Zinc yellow and iron oxide prime coats and zinc dust prime coats have tested well under aluminum finish coats. The leader of the 1941 series is a blue lead panel. Inhibitors of the phosphoric acid-dichromate type have been shown to have value in some instances.

Fifteen Panels Applied in 1944

Under the no-sand-blast procedure, 15 panels were applied in 1944. The treatment was wire brushing, which removed rust and loose paint, but had little effect in removing the adhering phenolic varnishes of the previous test, followed by inhibitor over the entire panel. All answered the bell for 1948 inspection but only seven survived for 1949. For some, such as chlorinated rubber or vinyl type paints, little could be expected in application over the phenolics but, at that, they gave some protection for four years. In 1948, a special chemical was used to soften the paints for removal by wire brush, and paints were applied to a clean surface which, where not rusted, had a bluish gunmetal appearance.

In general, the question of degree of paint removal involves the economics of the individual case. If the work is a painting job only, with cofferdam or docking charges against the job, sandblasting is a small percentage of the total cost, so the best work that can be produced is the cheapest in the long run. In a case where other repair requirements set the schedule, the painting may be only so good as the time permits, sufficient only to afford protection until the following repair job. In some work the deciding factor is whether the maintenance and operation people will permit sandblasting, or prohibit it because of liability of damage to nearby machinery. The question of adherence between old and new painting, and difference in cost of removal, and surface preparation are additional important factors, where painting is incidental to other maintenance work.

Atmospheric Exposure Types Worked Out

The type of paints to use on metal work subjected to atmospheric exposure only has been worked out to permit oil base paint as shop coat, with field coats being aluminum in phenolic varnish. On some recent contracts having submerged-type surfaces, the use of phenolic varnish paint for shop coat has been introduced. There is a question as to the advisability of

using oil base shop coat under phenolic resin paints. If sufficient drying time is provided for the shop coat, it is possible that direct application of phenolics over the shop coat, if clean, may prove satisfactory. Tests to check on this may be made on a bear trap, which should afford accelerated results.

Of the newer synthetic paints, such as vinyls and chlorinated rubbers, the first Pittsburgh tests were in the repair series of 1944 and failures occurred by blistering due to incompatibility between the old and new paints. The Navy wash primer and vinyls have been included in the 1948 and 1949 series of tests in which practically all previous paint was removed. The lesser susceptibility to unfavorable moisture conditions in application, and possibly lesser overall time for a job, and the lesser initial precautions after application of wash primer, are factors favoring the vinyls. In addition vinyls which permit other finish coats are being considered. The total thickness of a vinyl system may approximate that of a phenolic resin system.

In the synthetics "sand in second coat" has been tested. Properly applied, such systems provide much thicker second and third coats, and a physical interlocking bond between coats. Total thickness runs twice to three times the unsanded jobs.

While a multiplicity of paints in any system is to be avoided as a point of simplicity of field operations, a vinyl which will take a phenolic sanded top coat system might have interesting characteristics.

Other Tests Initiated

Other tests have recently been initiated on bear traps. The tests included both vinyl type, and phenolic-vehicle paints which have shown long-life characteristics in other underwater painting tests. The phenolic-vehicle paint was taken from Corps of Engineers' stock and applied by field forces. The vinyl paint panels were prepared in manufacturer's shop and installed by field construction forces. It is probable that more extensive tests will be placed this year, if the present do not show unfavorably.

Due to the rigorous conditions, it is anticipated that the paints may not afford protection for a long period. However, here some pretty definite comparisons can be made, based upon the following:

The number of repairs (over-hauls) of the trap and its age will give the average period between over-hauls.

The cost of the latest over-haul can be taken as expected cost, and the current value of a year's interval can be obtained.

The expected life of a paint job and its estimated cost will furnish the cost per year of this type of protection.

The current value of a year's interval can be compared with the cost of a year of protection. If this shows a balance favorable to painting the net value of a painting job is this balance times years of life of the paint.

If the maintenance cost on a trap can be allocated as 80 percent to the lower leaf, the annual square foot figure is at least $1.50. Since painting costs should be considerably less under any set of conditions, the "paint it" advocates are now waiting to obtain a favorable term on tests, and designation of suitable materials, as a basis for consideration of a worth-while reduction in costs. Possibly an interesting outgrowth from these paint tests on bear traps would be the development of a method of accelerated field testing of paints, using the present field tests as a basis of comparison.

Stabilization of Costs Sought

Painting costs are not stabilized, and, because of varying conditions, cannot be, although an effort is being made to eliminate some of the special charges. On one large job extending over two seasons, the cost per square foot was about 50 cents. With better plant and organization this should be reduced slightly. On favorable docking jobs the painting cost should be under 20 cents. On special jobs charges may be surprising.

Another phase is whether to deliberately lose material by abandonment of maintenance with intent to replace the whole when necessary. If the principle is to maintain a facility once it is established, a planned outage may not be justifiable if maintenance, at even equivalent average cost, can avoid such an occurrence. The intent is to reduce the average maintenance cost so a clear dollar saving is apparent, without resort to appearance value and credit for avoidance of planned outages for replacement.

In conclusion, it may be said that insofar as corrosion problems are involved, the Ohio River Division is interested primarily in what specifications and operation procedures will produce better and more worthwhile results. The problems are many and varied and if there be one answer probably it would have a number of subdivisions. Some progress in methods has been made since the war. Further improvements may be just over the horizon.

DISCUSSION

Comment by A. W. Peabody, Ebasco Services, 263 Houston Ave., Jackson, Miss.:

Concerning that part of Mr. Davenport's paper in which he indicated plans are being made for using graphite anodes for cathodic protection of Ohio River "bear traps" and that the graphite anodes are to be mounted directly on the lower leaf of the trap, I would like to know if it would not be more satisfactory to locate the anodes in the river bottom or river bank and direct current from them to the exposed metal surfaces of the bear trap. Without knowledge of full details of the installation this would appear to be a cheaper procedure.

Author's Reply:

For some time such an arrangement has been contemplated and a request for a trial has been made to higher authority. While authority has been withheld, it is my understanding it would soon be issued.

Since the St. Louis meeting a similar test has been authorized under the supervision of the Upper Mississippi Valley Division. I am keeping in touch with the experiment and at some future date should be in a position to give detailed information thereon.

Flame Sprayed Plastic Coatings*

By BERNARD GOLDBERG*

Abstract

The history of flame spraying is briefly reviewed. Both guns and powder containers used for applying flame sprayed coatings of plastic powders are described in some detail. Necessary criteria for organic materials both thermoplastic and thermosetting are indicated. Problems involved in producing suitable powders of tough non-friable resins are discussed and indications given of several promising solutions. Properties of flame sprayed Thiokol (a polysulphide synthetic rubber) coatings are reviewed in some detail. Recent work on improvements in flame spraying technique are illustrated by a discussion of the advances in the flame spraying of various polyethylene compounds. This includes comments on current theory, various fuel gas combinations and polyethylene compounding for obtaining specific properties in flame sprayed coatings. Some data is presented on the effect of after-treatments of flame sprayed plastic coatings. Experimental work being done on producing flame sprayed coatings of fluorinated hydro-carbons is described, and a preliminary report given on the properties of these coatings. Recent developments in the technique for producing smooth non-porous coatings of hot melt compositions is discussed in some detail. Procedures developed for producing sprayable powders of hot melt composition and for stabilizing them for storage are described. An indication is given of results obtained to date and probable effect of future developments in this field. In an attempt to indicate how the corrosion engineer can evaluate the suitability of flame sprayed plastic coatings for a particular corrosion problem, the history of several successful applications is reviewed.

FLAME SPRAYED plastic coatings are coatings produced by projecting at a properly prepared target particles of coating material that have been melted or at least made plastic by passage through a high temperature flame.

Metallic coating have been produced by similar techniques on an experimental basis for at least fifty years and commercially at least since World War I. Metals lend themselves to this technique particularly well, since they have sharp melting points and low viscosities when molten. The metals may be introduced into the flame either in the form of wire or in the form of powders. For corrosion resisting applications, metal sprayed coatings of zinc and aluminum have been used very successfully for protecting iron and steel against atmospheric and other mild corrosive conditions. They have the advantage over other types of anodic coatings that they can readily be applied in the field, that their thickness can easily be adjusted in accordance with the corrosive environment, and that their naturally porous structure offers an excellent base for paints or other organic finishes. Metal sprayed coatings of metals cathodic to iron have found little use as corrosion resisting coatings for steel since with coatings of a reasonable thickness moisture can reach the intefrace through the pores where the couple will be such as to promote corrosion of the steel, resulting in loss of adhesion. In special cases, ingenious methods may be worked out for avoiding this difficulty but cathodic coatings are not widely used for this purpose.

Flame sprayed plastic coatings are satisfactorily produced only by powder flame spray guns because plastic filaments which might otherwise be used in wire type metal spray guns have, in general, too poor thermal conductivity to be able to be melted and atomized in a flame. The Schori flame spray gun, which was the first of the commercially practical powder spray guns and is still the one most widely used for producing flame sprayed plastic coatings may be examined as representative of modern powder flame spray guns.

Essentially, the gun consists of a Venturi nozzle which creates a suction that is used to suck powder into the gun and which also projects this powder suspended in an air stream through a ring of flame which may be either an oxy-propane or air-acetylene flame. When using an oxy-propane flame, the flame is surrounded by a ring of compressed air which serves to keep the nozzle cool and the oxygen and propane are mixed within the gun to give a com-

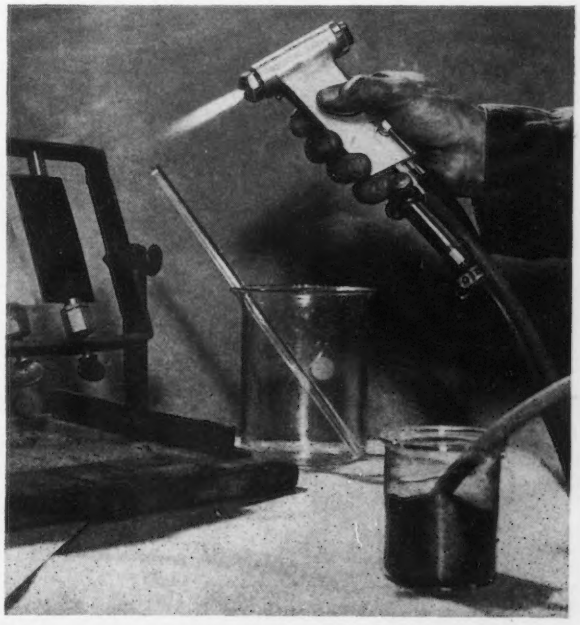

Figure 1—Model L flame spray laboratory or experimental pistol for spraying metals and plastics on small objects or sample test plates and jigs.

★A paper presented at the Sixth Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., April 4-7, 1950.

* Director of Research, Schori Process Division, Ferro-Co Corp.

bustible mixture. When using an air-acetylene flame, no cooling air is required nor is premixing of the air and acetylene.

Standard types of powder containers consist of an hourglass with two metering orifices at the neck, between which is a connection through which powder entrained in air is drawn by the suction hose. Other types of powder containers are available for special conditions. For example, one recently developed for the Navy Department utilizes a fluidizing bed[1] to feed a particular plastic powder which is not at all free-flowing and which cannot be metered through an orifice. In all cases control of the flow of powder by the operator is by means of a simple bypass hole connected to the Venturi nozzle. When this is closed by the operator's finger, powder is drawn from the container. When the finger is removed from this hole no powder is drawn by the Venturi, but air is sucked through this bypass.

Original flame sprayed plastic coatings were produced in England using bituminous powders about fifteen years ago. These coatings were reported to be fairly widely used in England for waterproofing and as corrosion resisting coatings under conditions of temperature and exposure where bituminous coatings were satisfactory.

Early work in this country sought to establish criteria for organic materials that would determine whether or not they could be sprayed. It was soon found that it was necessary and sufficient for a plastic to be sprayed that there be a wide range of temperatures in which the material was plastic and yet was not badly degraded either by the heat or by other chemical effects of the flame. Of course, other criteria such as adhesion, durability, chemical resistance, etc., were necessary in order to produce useful coatings but this one criterion was all that was required in order to determine whether a coating could be produced of any given material.

It soon became apparent on investigating available materials for producing flame sprayed plastic coatings that would be useful to industry, that a fundamental problem was that the tougher and stronger a material was and hence the better for most applications, the more difficult it would be to produce a fine powder of the material by conventional mechanical grinding methods.

Accordingly, several techniques were developed for producing fine powders of tough, non-friable plastics. Some materials can be polymerized in the form of fine powder and by agglomerating this fine powder a 50-mesh particle can be made that will be free flowing and yet have the large surface-to-volume ratio characteristic of very fine particles. Some materials that are not friable at room temperature can be mechanically ground by chilling them with dry ice and chilling the mill while grinding. Some materials can be atomized from the molten state in essentially the same way metal powders are made. Some materials can be reduced to a fine powder by precipitating them from solution.

The first large scale practical result of the investigation was the development of a coating of flame sprayed Thiokol. Thiokol is a synthetic rubber of the alkali polysulphide type that is quite tough and abrasion resistant and particularly resistant to the action of solvents and both fresh and salt water. Flame sprayed Thiokol has been used very widely by the Navy Department as a corrosion resistant coating for shafts, struts and rudders of combatant naval vessels where conditions of extreme erosion by fast moving salt water are encountered and is still being used for this purpose on quite a large scale. Surfaces are normally sandblasted before application of the coating and preheated somewhat. The original coating used by the Navy Department was found to be somewhat too brittle at low temperatures such as those encountered in drydock in extreme northern locations. Accordingly, it was found possible to add a "vulcanizing" or "polymerzing" agent to the powder before spraying. While complete polymerization is not obtained during the spraying and subsequent cooling of shafts and rudders, enough does occur to increase appreciably the toughness and low temperature flexibility of the compound. The present coating gives, very satisfactory performance for several years under the conditions of service, when the coating has been properly applied by skilled personnel.

When polyethylene was introduced into the American market on a large scale shortly after the war, it appeared to offer great promise as a raw material for a flame sprayed plastic coating. Preliminary work with it indicated that it produced very tough coatings of exceptional resistance to chemicals and with very good electrical properties. It was noted, however, that adhesion tended to be weak and that some degradation took place in the act of spraying so that the full chemical resistance of polyethylene sheet was not realized in the sprayed coating. Much work has been done therefore in an attempt to avoid these difficulties.

A recent paper by two Dupont chemists[2] tells of their investigation of this problem. They concluded that adhesion could be obtained by preheating the surface to be coated to a temperature between four and five hundred degrees F. and by the addition of graphite to the coating. They also concluded that the only way to avoid degradation in the flame was to use a long, relatively low temperature flame (as an air-acetylene flame) and supply the balance of the heat required to melt the particles being sprayed by the heat content of the preheated target. This limits the area to be preheated and sprayed at a time to between four and six square feet, they assert. Larger areas and done in patches four to six square feet each and they describe a technique for fusing these patches to each other. Unpublished work that has been done in the laboratory of the Schori Process Corporation corroborates the fact that this technique does produce coatings with satisfactory adhesion and negligible degradation. However, there appear to be modifications of this technique that also produce such coatings and that are believed to be more practical. Adhesion of graphite modified flame sprayed polyethylen can be obtained even without preheating by chemical pretreatment of the sandblasted surface. The use of an air-acetylene flame is desirable but it requires only a special nozzle to use this flame with

a standard Schori gun. Some pre-heating of the surface is desirable to minimize degradation, but for this purpose alone, once arhesion has been secured by other means, moderate temperatures are satisfactory.

By using higher molecular weight polyethylene than was used by the Dupont engineers, tougher coating with better chemical resistance can be produced. For example, the Dupont engineers reported that in room temperature exposures, flame sprayed polyethylene withstood dilute and concentrated hydrocloric acid, dilute and concentrated sulfuric acid, dilute nitric acid, concentrated hydrofluoric acid, dilute and concentrated acetic acid, concentrated formic acid, dilute ferric chloride concentrated sodium hydroxide and saturated sodium chloride and formaldehyde while it did not withstand concentrated acetic acid and concentrated nitric acid. The higher molecular weight polyethylene, however, withstood all these solutions. Also, for cases where the very great corrosion resistance of pure polyethylene is not required, compounds consisting primarily of polyethylene have been developed by Schori which in themselves have good adhesion to steel and do not require extensive preheating of the surface in order to form good films without degradation.

For coating objects where field application is not required but plant application is satisfactory, various other techniques of application and after-treatment have been developed that permit cheaper coatings. For example, machines have been developed for automatically spray coating with polyethylene dross and various types of widely used tanks of size and shape similar to 55 gallon drums. Small tanks can also be plant coated successfully without chemical pre-treatment or preheating by baking the coating after application.

A similar technique of baking coatings after application has been used to apply flame sprayed coatings of combinations of polyethylene and chlorotrifluorethylene. These coatings appear to have properties intermediate between those of each of the ingredients. Such coatings are, of course, very expensive and experimental work on them is at present quite limited. However, they do appear to give promise of producing coatings that will be useful at higher temperatures than will polyethylene alone.

A recent development that may be of interest is the establishment of a technique for applying satisfactorily by flame spraying, coatings of various hot melt compositions that are currently used by the Navy Department for anti-corrosive and anti-fouling use. These hot-melt compositions may be prepared in powder form of the proper particle size distribution either by grinding at dry ice temperatures in a conventional high speed hammer mill or by atomization from a hot melt through a pressure atomizing nozzle. Powders can be kept from agglomerating during room temperatures storage by dusting with anti-stick agents such as talc or various stearates. Very high rates of application have been achieved when flame spraying these compositions, of the order of several hundred square feet per hour. Since these materials are essentially relatively inexpensive, this development gives promise of leading to considerably less expensive flame sprayed plastic coatings than have been previously available for exposure conditions where they are suitable. Such coatings are, of course, sprayed in such a manner as to give completely nonporous surfaces as are all flame sprayed plastic coatings that are useful to industry.

In an attempt to indicate how the corrosion engineer can evaluate the suitability of flame sprayed plastic coatings for solving a particular corrosion problem, several case histories will be related.

A distributor of sodium hypochlorite solutions used as bleaches by laundries sought a container that would give better service than the rubber lined drums he had previously used. A consideration of the corrosive condition, the temperature range likely to be experienced, the mechanical abuse to which these containers were to be subjected and the cost of rubber lined drums led to the belief that a Hackney thirty gallon barrel lined with flame sprayed polyethylene might be satisfactory. A preliminary test of flame sprayed polyethylene in sodium hypochlorite solution did not appear to be necessary, so a few lined drums were placed in service. It appeared after a few months experience with these drums that from all points of view these drums were giving perfectly satisfactory service. Mechanical testing indicated that a coating thickness of about fifty mils gave satisfactory performance. Accordingly, a machine was constructed for automatically preheating and spraying Hackney drums with a 50-mil coating of graphited polyethylene of medium molecular weight.

A coating was desired to coat the interior of penstocks leading from one of the large Western dams. The problem was one of resistance to continuous immersion in fresh water with a high velocity of flow at all times. High rates of application and low cost was considered essential. A preliminary laboratory evaluation indicated that a flame sprayed application of the Navy Department's anti-corrosive hot plastic coating over primed sandblasted steel satisfactorily withstood the exposure. Acordingly, a large test area of one penstock was sandblasted and primed and then a thirty mil coating of the Navy's hot plastic anti-corrosive was flame sprayed. After six months exposure, the coating appeared to be performing satisfactorily except in areas where inspection of the coating had mechanically damaged it.

A large chemical manufacturing company had the problem of lining a centrifuge to be used with a solution that would be extremely corrosive to steel but that could be satisfactorily withstood by polyethylene. The problem was the mechanical one of developing a technique that would enable one to coat satisfactorily as complicated a structure as a centrifuge basket. In particular since the shell of the centrifuge was at least three-eighths of an inch thick and the holes were only one quarter of an inch in diameter, there was some doubt as to whether a satisfactory coating could be flame sprayed on the inside of these holes. A technique was developed for coating them satisfactorily. Extruded polyethylene tubing was inserted inside each small hole and then the balance of the centrifuge was sprayed. The flame sprayed polyethylene coating bonded satisfactorily to

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the pieces of extruded tubing and the whole assembly after coating showed no pinholes on inspection with a 15,000 volt spark.

It will be considered that this paper will have served its purpose if it makes the corrosion engineer aware of the possibilities inherent in this relatively new field of protective coatings-flame sprayed plastic coatings, and will cause him to consider their use when faced with a corrosion problem where conventional solutions appear inadequate either for reasons of cost or protection available.

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Summary and Conclusions

Report of Protective Coatings Investigation *Underwater Exposure Tests, 1941-1949**

By H. W. MUNDT, L. J. THOMPSON* and S. J. STACY**

Summary. This report and its appendix present the results of inspections and observations of the performance of selected protective coating systems in submerged fresh water exposure on the Isthmus covering a period of approximately eight years.

The results described were derived from performance tests of panel-specimens continued after immediate information from accelerated and/or short-term tests had been obtained during 1940-1942 for basing specifications for protection of the new locks and other structures planned under the Third Locks Project. The tests were continued until service performance had reached a repaint rating value of **6**, or until complete deterioration had occurred if this information was considered desirable or necessary.

Summary information is included covering the performance of the systems selected for protection of two submerged steel lift gates installed in the Panama Canal Locks. Comparison of the protective coating systems on the basis of individual elements which could alter the performance behavior beneficially or adversely has been accomplished wherever possible. In addition, an effort has been made to correlate the long-term performance data with the short-term or accelerated test results. Within the limits of the investigation, it is believed that all significant data and comparisons have been presented.

Conclusions. The following are the major conclusions:

a) The systems which show outstanding performance are those which have been zinc-metallized.

b) Zinc-metallizing provides a sacrificial prime coat which acts as secondary protection if and when the organic top-coats have deteriorated or become damaged.

c) Zinc-metallizing is not considered justifiable if the length of the service period is relatively short, e.g., 4-5 years, and regular maintenance repairing or repainting is the rule at the end of such relatively short periods.

d) For priming zinc-metallized surfaces, zinc tetroxychromate pigment in Bakelite resin BR-254, 60 percent tung oil, 40 percent linseed oil, 25 gallon length vehicle, pigment vehicle ratio 65/35 is best.

e) For sandblasted surfaces, zinc dust (80 percent)-zinc oxide (20 percent) in the aforementioned vehicle is best.

f) Systems which coat metal surfaces from which millscale has not been removed show worst performance.

g) The critical value for film thickness (Series A and B systems) appears to be about 4-5 mils minimum for a service life minimum of approximately 5 years with the following exceptions:

1) Zinc-metallized specimens which probably have not reached the end of their service life.
2) Sandblasted and millscale-intact specimens coated with Systems 1B, 4B, 5B and 6B.

(Note) The lack of durability of the systems in (2) may be due to the apparent degrading influence of zinc chromate which was included in the prime coats of these four systems.

h) Short-term and/or accelerated tests may be unreliable as long-term performance indicators, and should be used for this purpose only in conjunction with available service records for materials similar to those being considered.

* This report, dated March 1950, was based on investigations conducted by the Department of Operation and Maintenance, United States Panama Canal, Balboa Heights, Canal Zone. The excerpt printed was authorized for publication by Canal Zone authorities. A copy of the report was received by NACE Central Office on August 28, 1950.

Summary and Conclusions

Report of Metals Corrosion Investigation, Immersion Tests

*Five Years Duration, Initiated 1941**

By H. W. MUNDT, L. J. THOMPSON* and S. J. STACY**

Summary. The results of field immersion exposures of a selected group of welded and bare uncoupled ferrous and non-ferrous metals in Isthmian fresh, brackish, and sea waters for durations of one, three, and five years are presented by this report and its appendix. The tests which were initiated in 1941 and completed in 1946 were conducted especially to obtain urgently needed information regarding the corrodibility of various basic and special purpose metals required by The Panama Canal for the maintenance of existing facilities and for additional facilities proposed for early construction. Results of the one year exposures were used as proximate information for the preparation of specifications for metal equipment for the proposed new locks and other metal structures planned under the Third Locks Project. The complete results made available in this report should provide useful general information for other purposes.

Conclusions. Within the limits of the investigation, major conclusions are as follows:

a) Exclusive of the welds, stainless steels, and zincs, the rates of corrosion in ipy are rather uniform and fall within relatively narrow range bands as based on the five year exposure results for each of the ferrous and non-ferrous groups if considered separately.

b) The rates of corrosion of the different grades of uncoupled zinc do not differ significantly if the results for the five year exposures and all environments are considered.

c) Considering the results as a whole, the continuous brackish water environment is the most aggressive of those tested.

d) As indicated by the five year exposures and considered as a group, excluding zinc, the non-ferrous metals show better resistance to corrosion in sea water than in fresh water, and least resistance in brackish water.

e) The welded sections of the majority of welded specimens exposed in sea water at mean tide were in good condition after exposure except: copper-nickel structural and copper bearing steels and nickel.

(1) The spread and average ipy values for the one year and five year exposures for the ferrous metals (low alloy steels and wrought iron) are as follows:

Environment, Water	EXPOSURE DURATION, YEARS					
	One			Five		
	Max.	Min.	Avge. (13)	Max.	Min.	Avge. (13)
Sea, Mean Tide	.017	.010	.014	.0075	.0044	.0056
Brackish, Continuous	.013	.0032	.0108	.0089	.0058	.0074
Fresh, Continuous	.0079	.0026	.0065	.0041	.0017	.0032

* This report, dated May 1950, was based on investigations conducted by the Department of Operation and Maintenance, United States Panama Canal, Balboa Heights, Canal Zone. The excerpt printed was authorized for publication by Canal Zone authorities. A copy of the report was received by NACE Central Office on October 30, 1950.

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Studies on Galvanic Couples*

I. Measurement of Electromotive Force and Internal Resistance of Cells During Current Flow*

By H. D. HOLLER**

Abstract

A method of measuring the effective electromotive force and internal resistance of a galvanic cell during current flow is described. A dry cell was used for demonstration of the method. By introducing a reference electrode into a cell consisting of an iron electrode and a magnetite electrode in wet clay, it was possible to measure the potential and resistance between the reference and electrode and either the iron or magnetite during current flow. When the iron and magnetite were short-circuited, the potential and resistance between the reference electrode and the iron-magnetite couple were measured. By impressing current upon the galvanic couple from an auxiliary electrode, the potential-current characteristic of the couple was determined. It was shown that an iron plate in wet clay exhibits such a characteristic similar to that of the galvanic couple.

Introduction

IN THE MEASUREMENT of internal resistance of a galvanic cell delivering current it is often assumed that the electromotive force maintains its open-circuit value. The emf driving the current is not necessarily constant, because a counter emf of polarization is usually generated, as the result of current flow. According to Ohm's law, the exact relationship is

$$\frac{E_1 - \Delta E_1}{R + r} = \frac{E_d}{R + r} = i \qquad (I)$$

where E_d = driving emf.
E_1 = open-circuit emf.
ΔE_1 = counter emf of polarization.
R = external resistance.
r = internal resistance.
i = current.

If E_d were measurable for known values of i and R, then r may be calculated from the above equation; or if r were known, E_d may be calculated. Also, since E_1 may be measured directly on open-circuit, the emf of polarization ΔE_1 may be found from the difference $E_1 - E_d$. Both ΔE_1 and E_d, and also the internal resistance, may vary considerably with the magnitude and direction of the current. These variations of E_d and r with current are, of course, manifestations of electrochemical processes occurring at the electrodes. We are dealing, therefore, with polarization phenomena and the problem is not only to measure the driving emf and internal resistance of a working cell, but also the potentials of the individual electrodes, and to indicate the role of the resistive components of the measured potential differences.

The measurement of electrode potentials without including the resistive components during current flow has long been a controversial problem.[1] It is particularly important (a) when the reference electrode cannot be in intimate contact with the electrode under investigation, or (b) when the electrode is covered with a film of high resistance.

Moreover, since any electrode may exhibit potential differences on its surface, giving rise to currents flowing from anodic to cathodic areas, it is effectively a system of galvanic couples. Therefore, its behavior, in a cell through which current is flowing, should be in accordance with the electrical relations governing the polarization of galvanic couples. So far as the writer is aware, the measurement of emf and internal resistance of cells has not been approached from this viewpoint: that electrodes usually act like galvanic couples. Any departure from this role is one of degree only.

A Wheatstone bridge having an adjustable counter emf for measuring emf without including the resistive component has been used.[2] This idea, together with modification of the bridge suggested in this paper, makes it possible to measure both the emf and internal resistance directly.

In addition, the technique described herein facilitates the use of a recording potentiometer for obtaining emf-time curves, provided the resistive component due to cell current does not change simultaneously.

Development of Technique

In developing this technique, it is necessary to consider the inherent properties of the Wheatstone bridge. For example, in Figure 1 which represents the simplest bridge circuit, if the resistances have such values that

$$\frac{r}{x} = \frac{Q}{D} \qquad (II)$$

then closure of key K in the branch containing the emf b will cause *no deflection* of galvanometer g. This is the condition of a balanced bridge. A resistance R_K may be used in parallel with K to limit the change in voltage applied to the bridge, when the key is closed, and thereby control sensitivity.

Let us now replace r with a cell having an emf E_d

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** National Bureau of Standards, Washington, D. C.

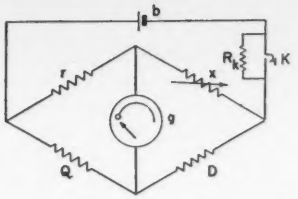

Figure 1—Most elementary Wheatstone Bridge.

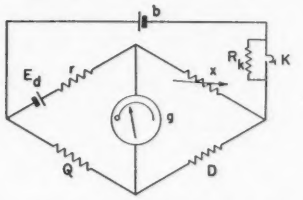

Figure 2—Elementary Wheatstone Bridge with emf in one arm.

and an internal resistance r, as in Figure 2, where r has the same value as in Figure 1. There is now a deflection of the galvanometer due to E_d. If the value of r changes, the bridge may be rebalanced with respect to the resistive component by varying X until closing or opening K causes *no change* in deflection.

Let us now see how the value of E_d may be measured. If an adjustable counter emf Vg is put in series with the galvanometer, we have the relations shown in Figure 3. Then according to Kirchoff's laws: in circuit:[2]

$$E_d - V_g = ir + i_g r_g - (I - i)Q \qquad (III)$$

r_g being the galvanometer resistance; in circuit (3)

$$V_g = (i - i_g)X - i_g r_g - I - i + i_g)D \qquad (IV)$$

Now, if $r = X$ and $Q = D$, then when i_g is reduced to zero by adjusting V_g until the galvanometer reads zero

$$E_d = 2V_g \qquad (V)$$

This is true for any equal values of Q and D. Using the same circuits of Figure 3, the relation between E_d and V_g may also be derived by the use of determinants.

As Pearson has shown,[2] the adjustable counter emf may be used in the same arm of the bridge containing the emf to be measured, and the latter be read directly as V_g. However, the circuit described here more readily permits the galvanometer and adjustable counter emf to be replaced by a recording potentiometer for obtaining emf-time curves for the cell through which current is flowing. If r should vary with current, the bridge may be rebalanced by adjustment of X, giving r directly. This may be done as described above, or with alternating current.

Application of Technique

Dry Cells

The main objective in this work was the study of cathodic protection, but the adaptability of the circuit in Figure 3 to the measurement of emf and internal resistance was demonstrated by applying it to dry cells. Two aged cells of miniature size, having a high internal resistance, were used for the tests. The potential difference V across the cell during current flow was measured with a high-resistance potentiometer. Then

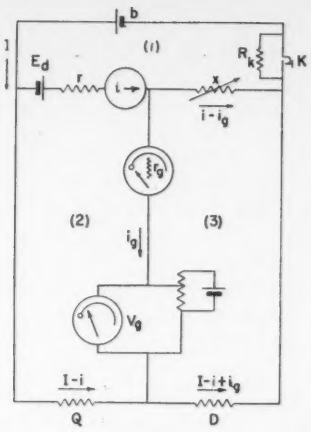

Figure 3—Wheatstone Bridge with emf in one arm and an adjustable counter emf in series with galvanometer.

$$V = E_d \pm ir \qquad (VI)$$

in which all quantities depend on the magnitude and direction of i.

In order to compare the values of r, measured with

TABLE I

Internal Resistance and Driving emf of an Aged Dry Cell for Different Currents

Current i(ma)	Resistance r(ohms)	E_d (Volts)	V Volts	(E_d—ir) Volts
		DISCHARGE		
1.00	470	1.220	0.740	0.750
0.83	470	1.220	0.838	0.830
0.60	420	1.226	0.991	0.974
0.25	250	1.244	1.112	1.084
		CHARGE		
				(E_d+Ir)
0.33	163	1.264	1.353	1.340
0.69	123	1.346	1.429	1.431
0.98	105	1.396	1.500	1.499

TABLE II

Comparison of Results of Measurement of Internal Resistance of an Aged Dry Cell, Using Direct and Alternating Current for Balancing Bridge

Current i(ma)		Internal Resistance r(ohms)	
		d-c	a-c
		DISCHARGE	
1.10	Time effect*.....	350	350
1.10	Time effect.....	312	313
1.10	Time effect.....	300	306
0.90		299	300
0.60		280	282
0.35		203	197
		CHARGE	
0.15		140	132
0.30		119	117
0.50		120	116
0.73		116	116

*"Time effect" indicates drift in readings during measurement.

alternating or direct current, 60-cycle current was also used for balancing the bridge, in which an a-c galvanometer served as null detector. The results of measurements are given in Tables I and II, and in Figure 4. The resistances of Q and D were each 100,000 ohms. The galvanometer had a period of 1.4 seconds and a sensitivity of 0.0070 microamperes per division. A short period is necessary in order that any deflection, due to an unbalanced bridge, will occur quickly and before any slower deflection caused by cell polarization.

The agreement between the values of the potential difference V across the cell obtained by direct measurement, and the algebraic sum, $E_d \pm ir$, is very satisfactory at the higher currents, showing that the measured value of r truly represents the effective internal resistance. At the lower currents, agreement was not so good because of lower sensitivity. Even though r changes with time, as well as with current, the results with direct and alternating current are in satisfactory agreement. No doubt, the values of the bridge resistances could be so chosen that lower or higher values of internal resistance may be accurately measured.

The internal resistance of these two dry cells is directional, as indicated by the values lower on charge than on discharge. This might be explained on the basis of dry-cell theory and experimentally by the use of a half-cell for investigating the zinc electrode and the carbon-manganese dioxide electrode separately. This was not done, since other electrodes were of primary interest, and we leave the subject of dry cells here.

Measurement of Electrode Potentials

Let us now consider modification of the circuit in Figure 3 for measurement of a single electrode potential paired with a reference half-cell. For example, in Figure 5 the cell consists of two electrodes, carbon C and a corrodible metal M such as iron, in an electrolyte, and between them is a reference half-cell S. Let r be that part of the internal resistance between S and the iron electrode, the latter being under investigation. Let this assembly in Figure 5 be substituted for E_d and r in Figure 3 and let E_x = the potential of the carbon electrode.

Then if the bridge is balanced by varying X until the closing or opening of key K causes *no change* in galvanometer deflection, and V_g is adjusted until the galvanometer reads zero, it follows that

$$r = X \qquad \text{(VII)}$$

and

$$E_M - E_s = 2V_g \qquad \text{(VIII)}$$

where E_M = the potential of the metal electrode, and E_s = the potential of the reference half-cell.

The reference half-cell used here was the carbon-manganese dioxide electrode of a dry cell. This electrode was made up by substituting, for the zinc can, a Lucite tube having a porous diaphragm which permitted electrolytic contact with the cell under investigation. It was designed for ruggedness in field work, and was used here because of convenience.

The values of the fixed equal arms of the bridge may be increased if necessary to reduce the current through the half-cell, and therefore its polarization, or they may be decreased to improve the sensitivity of the bridge.

In the measurement of electrode potentials in various electrolytes, it is soon realized that a metal does not usually exhibit its own potential, but behaves like a galvanic couple; that is, its observed potential lies somewhere between the potentials of the anodic and the cathodic areas on the surface.

If in Figure 6 we let e_a and e_c be the polarized potentials of the anodic and cathodic areas, respectively, and r_a and r_c be the corresponding resistances of the current paths between the half-cell and the same areas, ignoring r_s for the moment, then the potential of the metal elec-

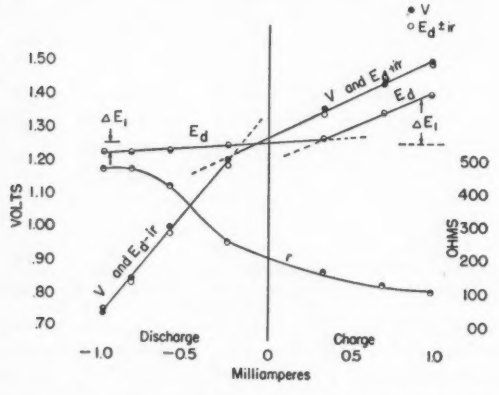

Figure 4—Measured values of internal resistance and emf of dry cell during flow of current.

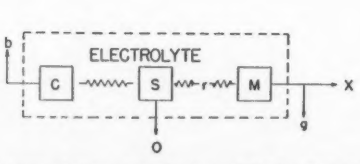

Figure 5—Diagram showing introduction of half-cell S into cell under investigation.

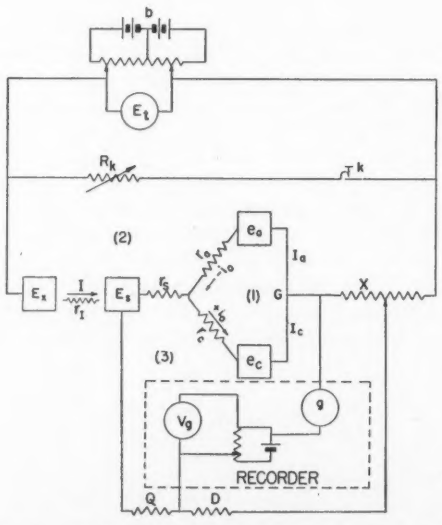

Figure 6—Diagram showing technique of measurement of emf and resistance for different values of E_t and I; also possible resistance in couple and introduction of potentiometer recorder.

trode, with reference to the half-cell S, may be represented by equation

$$E_G = e_a - i_o r_a \quad (IX)$$

$$= e_c + i_o r_c \quad (X)$$

Since $E_G = 2V_g$, a potentiometer recorder may be introduced in Figure 6 and calibrated to record E_G directly. A resistance R_K may be used in series with K to vary sensitivity as in Figure 6, or in parallel with K (Figure 3).

Resistance of a Galvanic Couple

In the Wheatstone bridge circuit, the metal electrode, behaving like a galvanic couple, will exhibit a certain rsistance R_G toward the bridge (external) current I. If E is the potential difference applied to the couple, which is equal to $E_t - E_x - I\ (r_I + r_s)$, then from Ohm's law

$$\frac{E - E_G}{I} = R_G \quad (XI)$$

To evaluate R_G, consider the circuit in Figure 6 where

$$\frac{E - e_a}{r_a} = I_a \quad (XII)$$

and

$$\frac{E - e_c}{r_c} = I_c \quad (XIII)$$

Neglecting the small current through Q and D, $I_a + I_c = I$. Adding we have

$$\frac{r_c(E - e_a) + r_a(E - e_c)}{r_a r_c} = I \quad (XIV)$$

But

$$e_a - e_c = i_o(r_a + r_c) \quad (XV)$$

which is independent of I.

At this point, it must be emphatically realized that the local current i_o is determined entirely by $e_a - e_c$ for given resistances in the network. Any effect which the external current I may have on i_o is the result of electrochemical action on $e_a - e_c$. Electrically, I and i_o are independent of each other.

Substituting the value of e_c from the preceding equation, in equation (XIV), and simplifying, gives

$$\frac{(r_a + r_c)(E + i_o r_a - e_a)}{r_a r_c} = I \quad (XVI)$$

Then introducing the value of $E_G = e_a - i_o r_a$ from equation (IX) we have

$$\frac{E - E_G}{I} = \frac{r_a r_c}{r_a + r_c}. \quad (XVII)$$

Therefore, from equations (XI) and (XVII)

$$R_G = \frac{r_a r_c}{r_a + r_c}. \quad (XVIII)$$

This equation may also be derived from the same circuits by the method of determinants, for any value of I, regardless of the magnitude or direction of I or i_o.

If, therefore, the bridge be balanced and the galvanometer reading be brought to zero by adjustment of V_g then

$$E_G - E_s = 2V_g \quad (XIX)$$

and

$$X = r_s + R_G \quad (XX)$$

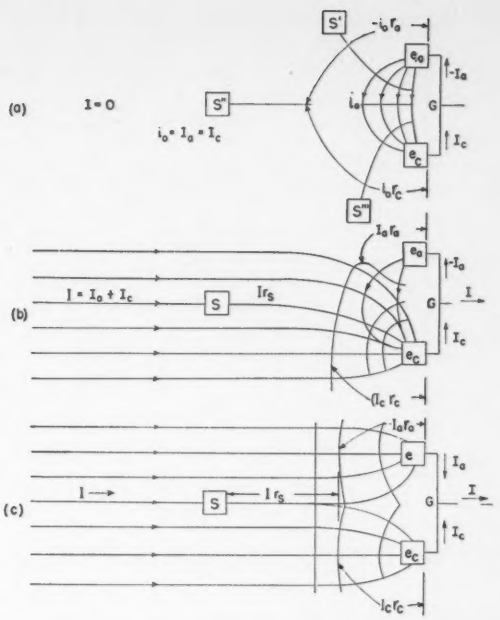

Figure 7—Diagrams showing relation of position of half-cell *S* to couple and effect of *I* and series resistance r_s on observed values of E_g.

where r_s is a series resistance depending on the location of the half-cell and the configuration of the electrode under investigation.

Relation of Position of Half-Cell to Observed Potential of Couple

These relations may be more easily visualized if we consider currents I and i_o superimposed on each other, their directions being determined by the emfs causing them; the resistance of the couple behaving like the resistances of the two paths in parallel.

When I — 0, the observed value of $E_G - E_s$ depends on the position of S, as shown in Figure 7(a), where the equipotential levels S′, S″, and S‴ are indicated. Any change in the position of S along one of these levels should not affect its potential reading. If the potential levels be unknown, then tests at various distances, say at S″ on a line perpendicular to the surface of the electrode, may be made in order to find an area in which further changes in position of the reference electrode make negligible differences in the readings. This may be considered a "remote" position.

If an external current I is impressed from a distant source, we have the situation in Figure 7(b), where the potential levels have been distorted by introduction of the resistive component Ir_s. The total resistive component of the potential difference between S and G is $Ir_s + I_c \cdot r_c$ along the cathodic path, or $Ir_s + I_a r_a$ along the anodic path, where r_s is common to both paths. The potential of the couple, referred to S, *including all resistive components* is then

$$E_G + I\ (r_s + R_G). \quad (XXI)$$

This is the value which would be obtained if the potential difference were measured with a potentiometer.

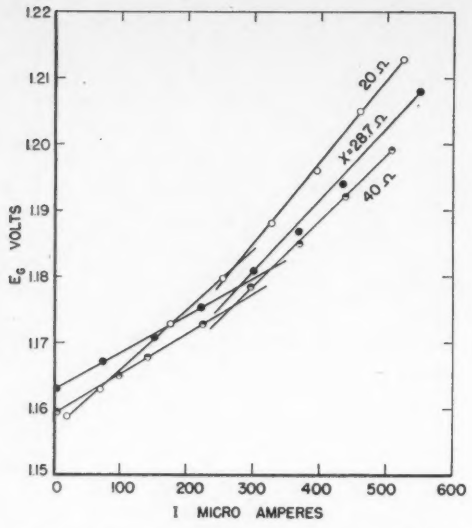

Figure 8—Data showing characteristic E_g/I of iron cathode for different settings of bridge.

Now, if I is increased until the potentials of the cathode and anode become equal, then I_a becomes zero. On further increase of I, I_a becomes positive, flowing to the electrode, formerly the anode. Then r_s may be defined as that resistance, through which all of I flows, extending from S to a point where the current divides between the anodic and cathodic paths. The resistance from this point on to G via anode path is r_a, and via cathode path r_c, the total resistive component between S and G as measured by a Wheatstone bridge being

$$I(r_s + R_G). \qquad \text{(XXII)}$$

Using the technique of first balancing the bridge and then adjusting the counter emf V_g until the galvanometer reads zero (Figure 6), we actually subtract the resistive component, represented by (XXII), from (XXI) and obtain E_G.

Technique Applied to an Iron Electrode

The resistances, r_a and r_c, are in series in the closed galvanic couple circuit,[1] Figure 6, but they are in parallel with reference to I which is also the bridge current. They may vary as a result of the passage of current in such a way that R_G may be changed. However, it is also possible for the enlargement of the current path to the cathode to occur, at the expense of the anode path, without changing R_G, unless the resistance of the anode path depends on direction of current.

By applying the above technique to an iron-plate electrode, 2 in. x 6 in. (5.1 x 15.2 cm), immersed in wet clay in a small container using a carbon-manganese dioxide electrode for reference, the graphs in Figure 8 were obtained, where X = 28.7 ohms.

A discontinuity in the graph for X = 28.7 ohms occurred at potential $E_G - E_s$ of about 1.178 volts, which was not far from the open-circuit potential of iron for the conditions given. A current of about 275 microamperes was required to make the iron plate behave as if it were cathodic, although the current density on its back surface must have been low. In a larger container, the current density would be more uniform and the possibility of any anodic areas on the back surface would be less. Then, the potential, at which the discontinuity occurs, should be nearer to the open-circuit potential of iron.

Changing the bridge setting from 28.7 to 20 or 40 ohms is similar to changing the calibration of a meter, and resulted in different slopes, but the discontinuities all occurred at nearly the same current of 275 microamperes. Accurate balancing of the bridge, therefore, is not necessary to obtain a potential-current characteristic of the electrode. The similarity between this characteristic for the iron-plate electrode in Figure 8, and that for the dry cell, suggests that the polarization characteristics of both are similar. The discontinuities in the values of E_d and V (Figure 4) may be related to the polarization characteristic of one or both of the dry cell electrodes. On charge, the graph E_d may manifest a change in potential of the zinc cathode, similar to that for the iron in Figure 8.

Apparent Film or Phase Boundary Resistance

In defining r_a and r_c as the resistance of the anodic and cathodic paths, respectively, it was tacitly assumed that the current distribution of I over the anode and cathode area was the same as that of i_o. This is not strictly true. Perhaps the best we can do in describing r_a and r_c is as represented in Figure 6, where the two resistances are joined to a series resistance r_s. The order of magnitude of r_a and r_c may be determined for couples of specific electrodes, which may be measured separately or together.

For example, in the case of a couple consisting of a rod of iron and a similar rod covered with magnetite, both in wet clay, the following bridge measurements were made:

$$X_1 = r_s + r_a = 22.0$$

$$X_2 = r_s + r_c = 37.4$$

$$X_3 = r_s + R_G = 20.4$$

Then, since

$$R_G = \frac{r_a r_c}{r_a + r_c}$$

by using the quadratic formulae, the following values were obtained: $r_s = 16$, $r_a = 6$, and $r_c = 21.4$.

Thus it is apparent that r_c, or the apparent boundary resistance of the cathode, is 3½ times greater than that of the anode. This is important in determining the partition of the current I between the anodic and cathodic areas. Thus

$$I_a = \frac{E - e_a}{r_a} \text{ and } I_c = \frac{E - e_c}{r_c}. \qquad \text{(XXIII)}$$

Then

$$\frac{I_a}{I_c} = \frac{r_c(E - e_a)}{r_a(E - e_c)} \qquad \text{(XXIV)}$$

which shows that the partition of current I is determined by the opposing emf, as well as by the resistance of each path.

Conclusions

The driving emf of a cell and its internal resistance may be determined simultaneously by a bridge-potentiometer technique. Both of these vary with the magnitude and direction of current through the cell. Applying the theory of polarization of galvanic couples, the reasons for some of these variations are explainable. To a potentiometer alone, an emf and a resistive component of a potential difference look alike. Using a potentiometer and a bridge as described herein, it is possible to differentiate between these components to an extent, depending upon the galvanic couples involved. By the introduction of a half-cell, both the emf and resistive component of polarization of the individual electrodes may be determined, remembering that each electrode itself may behave like a short-circuited galvanic couple. The circuit developed herein may be used for recording the emf of a cell carrying current without inclusion of the resistive component.

Any discussion of this paper will appear in a Discussion Section, to be published in the June, 1951, issue of the JOURNAL.

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II. Some Potential-Current Relations in Galvanic Corrosion*

Abstract

A graphic method of expressing the electrical characteristics of a galvanic couple was developed by the application of Kirchoff's laws to a couple consisting of separate electrodes, each with an ammeter in series. When an external emf was impressed between the couple and a third electrode, also with an ammeter in series, a definite current pattern was established, depending on the relative directions and magnitudes of the impressed emf and the potential of the couple. These relations were demonstrated with the iron-magnetite couple. Under the conditions used, a discontinuity in the potential-current relation was observed, when the couple was cathodically polarized over a sufficient range of current. This discontinuity or "break" coincided with reduction of current, circulating within the couple, to zero. The rise in potential at this point is the logical result to be expected from the hydrogen overvoltage.

Introduction

In the measurement of the so-called "static" electrode potential of a metal in a given electrolyte, without measurable current flowing to or from the electrode, it is usually assumed that the measured value represents the potential of the metal itself. This can be true only when there is no local galvanic-cell activity on its surface. For example, if we put iron, the metal which concerns us most in this discussion, in air-free water, the following reaction occurs:

$$Fe(s) + 2H_2O(1) \rightleftarrows Fe(OH)_2(s) + H_2(g) \qquad (I)$$

which proceeds until a pH of about 9.5 is reached. This is determined by the solubility-product and stability of ferrous hydroxide.

We then have the galvanic cell

$$Fe/[Fe^{++}]//[H^+]/H \qquad (II)$$

where the anodic reaction is,

$$Fe(s) \rightarrow Fe^{++} + 2\varepsilon \qquad (III)$$

and the cathodic process is

$$2H^+ + 2\varepsilon \rightarrow 2H \rightarrow H_2(g). \qquad (IV)$$

If we now introduce a third electrode such as the normal calomel, for reference, into the electrolyte and measure the difference in potential between it and the piece of iron, we obtain a reading which does not represent iron alone, but lies somewhere between the potentials of the iron anode and the hydrogen cathode. Thus in Figure 1, the measured difference in potential is $E_G - E_s$ where E_G si the potential of the Fe/H couple, and E_s is that of the reference electrode, i_o being the cell current. Here, E_{Fe} = potential of iron, and E_H = potential of hydrogen, when $i_o = 0$.

The potential level E_G is determined by the emf components of polarization, ΔE_{Fe} and ΔE_H, and by the resistive components $i_o r_a$ and $i_o r_c$, where r_a and r_c are the resistances of the current paths between the reference electrode and the anode and cathode, respectively. All of these components are functions of i_o. If $i_o = 0$, then and then only, $E_G = E_{Fe}$, the true potential of iron.

Since E_H and, to a lesser extent, E_{Fe} depend upon the hydrogen ion activity of the electrolyte, the emf of the Fe/H couple is related to pH (Figure 2).[1] The electrode potentials of hydrogen and iron become nearly equal at a pH value of about 9.5 and, consequently, the emf of the cell (II) approaches zero. Over a range of several pH units near the neutral point, e.g., from pH 5 to pH 10, E_{Fe} varies only a few millivolts, while E_H changes 58 mv per pH unit. At a pH 5, the emf of the Fe/H couple is about 0.20 volt.

While the approach of E_G toward the higher level of E_{Fe} caused by increasing values of ΔE_H will be accompanied by a reduction in i_o (cathodic control) and, therefore, in corrosion rate, it is possible under certain conditions that the polarization component ΔE_{Fe} may become very large with the result that E_G approaches the lower level of E_H, also accompanied by a reduction in i_o (anodic control), and consequently, a decrease in rate of corrosion by galvanic-

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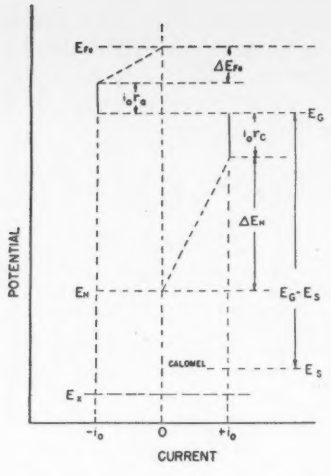

Figure 1—Diagram showing electromotive force $E_G - E_s$, between E_G, potential of iron-hydrogen couple, and E_s, potential of reference calomel electrode.

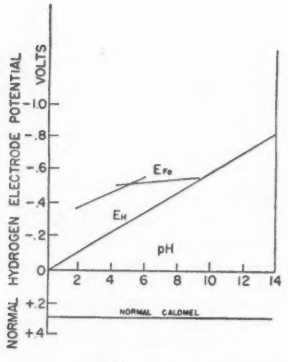

Figure 2—Relation of potential E_{Fe}, of iron in air-free electrolyte (according to data summarized by Gatty and Spooner) to potential E_H of hydrogen at different pH values.

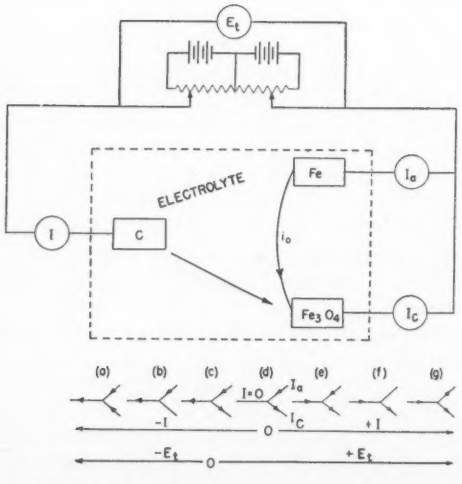

Figure 3—Diagram showing technique for determining relation between applied potential, E_t, and currents through Fe/Fe_3O_4 couple and external electrode, carbon.

cell action. It is apparent therefore, that the value of E_G alone should not be taken as a guide to indicate corrosion rate, and that an increase or decrease in E_G should not necessarily indicate an increase or decrease in corrosion rate; but its interpretation must be related to other simultaneous observations such as those obtained when the galvanic cell is subjected to applied external current.

Behavior of a Galvanic Couple Toward External Current

The behavior of a galvanic cell toward an externally applied potential depends primarily upon the relative values, directions, and changes in emfs involved. If, for example, in Figure 3, we impress a potential E_t between an iron-magnetite couple and an external electrode of carbon C, we obtain one of the Kirchoff patterns indicated. At this point, it should be pointed out that, since the activity of the couple results in liberation of hydrogen on the magnetite cathode, we are really dealing with the Fe/H cell represented in Figure 1.

The potential E_x of carbon is below E_G and calomel in Figure 1. Therefore, when an applied potential is gradually increased, beginning at zero, external current I will not flow to the couple until

$$E_t > E_G - E_x$$

and then it will flow first to the cathode because its potential is exceeded first. As E_t is increased, current will continue flowing to the cathode, until its potential becomes equal to E_{Fe}. Then, and then only, will current flow to the iron. This phenomenon depends entirely on polarization of the cathode, the term polarization being used in its broader sense to include both counter emf and the resistive component, caused by current flowing through resistance. When the applied potential E_t just balances the potential of the galvanic couple E_G, there is no external current. Then

$$E_t = E_G - E_x$$
$$I = 0$$
$$I_a = I_c = i_o \text{ (pattern d).}$$

When there is no applied potential, current flows from the iron anode into the external circuit. Then

$$E_t = 0$$
$$-I = -I_a + I_c \text{ (pattern c).}$$

When $E_t > E_G - E_x$, external current flows to the cathode (pattern e). Now, if the polarization of the cathode ΔE_H is increased, its potential moves toward that of iron. When

$$E_H + \Delta E_H + I_c r_c = E_{Fe} \text{ (Figure 1)}$$

then

$$E_t = E_{Fe} - E_x$$
$$I_a = 0$$
$$I = I_c \text{ (pattern f).}$$

On further increasing E_t above E_{Fe}, current flows to both electrodes. Then

$$E_t > E_{Fe} - E_x$$
$$I = I_a + I_c \text{ (pattern g).}$$

Likewise, if the anode can be polarized by increasing E_t in the negative direction until

$$-E_t = E_H - E_x$$

then

$$I_c = 0$$
$$I = I_a \text{ (pattern b).}$$

On further increasing E_t in the negative direction until

$$-E_t > E_H - E_x$$
$$-I = -I_a - I_c \text{ (pattern a).}$$

If I, I_a, and I_c are plotted for different values of E_t, the relations shown in Figure 4 are obtained. These graphs are not necessarily straight lines, but at the potential levels where

$$E_t = E_{Fe} - E_x$$
$$E_t = E_G - E_x$$
$$E_t = E_H - E_x$$

the current relations are rigidly fixed by Kirchoff's law. The galvanic-cell current i_o is indicated for the condition when $E_t = E_G - E_x$, that is, when $I = 0$. I_a is reduced to zero, when $E_t = E_{Fe} - E_x$. The value of I at this potential level is I_p, the "protective current," where the iron becomes wholly cathodic and is completely protected from corrosion. I_c may also be reduced to zero when $E_t = E_H - E_x$. The value of I at this level is I_q, but is not wholly protective since the couple is now all anodic, and may corrode in accordance with Faraday's law, or become passive.

By simple trigonometry

$$i_o = \frac{I_p I_q}{I_p + I_q} \qquad (1)$$

When it is possible to estimate I_p and I_q, i_o may be calculated, even though not directly measurable.

In Figure 5, actual readings on an iron-magnetite couple are shown. The computed maximum value of i_o agrees very closely with the measured value, when $I = 0$. It is apparent that the graphs are not single straight lines, but generally intersecting straight lines. For example, at the current I_p, where iron becomes cathodic, there is evidence of a discontinuity. If we knew the slope of I_c, we could estimate the value of i_o. For example, in Figure 5, the ratio $\alpha = i_o/I_p$ is approximately 0.6. An experimental determination of I_p, therefore, would show how much current is necessary to protect the anode from corrosion, and also, when multiplied by α would indicate the rate of corrosion without cathodic protection. The study of a number of such couples would tell us whether this ratio is characteristic of the couple. If it is, then the rate of corrosion is

$$\frac{W}{t} = \alpha I_p \cdot k \qquad (2)$$

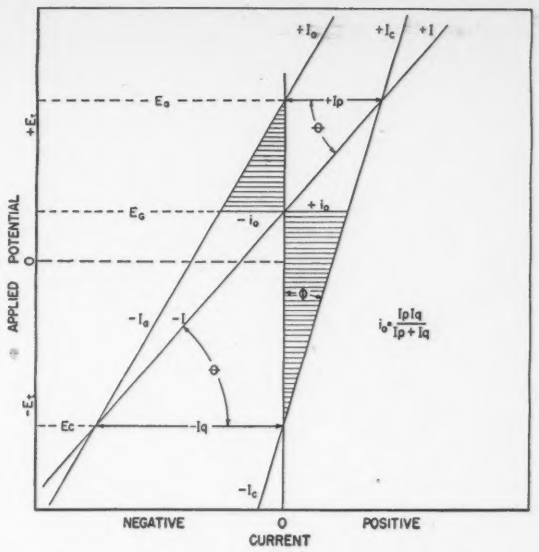

Figure 4—Diagram showing hypothetical relations between applied potential E_t, and I, I_a, and I_c.

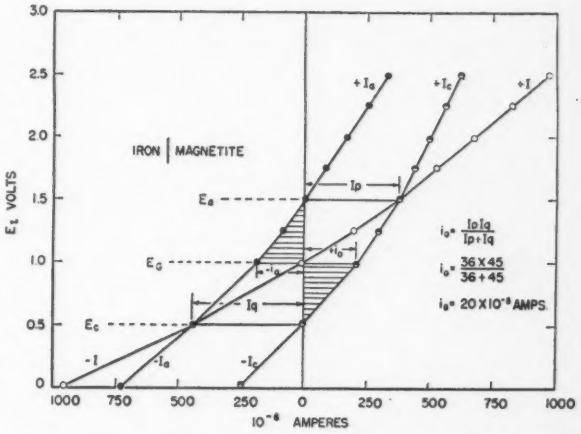

Figure 5—Experimentally determined relations between applied potential E_t and current I, I_a, and I_c.

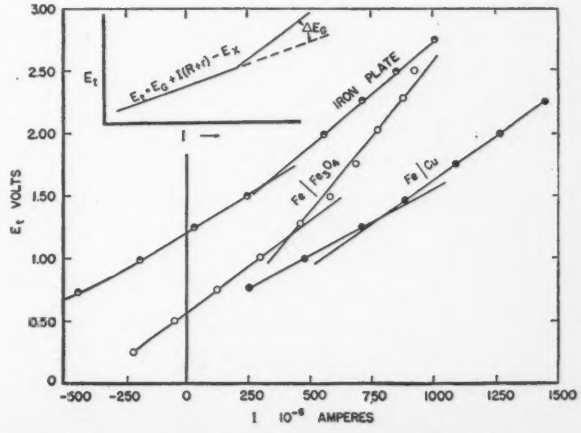

Figure 6—Experimental relations between applied voltage E_t and external current, I, for Fe/Cu and Fe/Fe_3O_4 couples and for iron plate.

where W = metal lost by corrosion, t = time, and k = the electrochemical equivalent of the metal.

While it is clear that corrosion is stopped by the application of current I_p, experimental evidence of this fact is required. If E_{Fe} be known, then I_p is simply that current necessary to polarize the cathode until its potential $e_c + I_c \cdot r_c$ becomes equal to E_{Fe}. The requirement of this procedure is two-fold: first, a determination of E_{Fe} in the particular environment by a suitable technique, and second, a method of determining when the potential corresponding to $e_c + I_c r_c$ is attained.

Estimation of Protective Current

We have in Figure 6, the relation between E_t and I for Fe/Cu and Fe/Fe_3O_4 couples in wet clay, which is representative of air-deficient conditions, where liberation of hydrogen may be expected. The intersection of the two straight lines in each case occurred at the value of I_p required to reduce I_a to zero. A similar pair of intersecting straight lines was obtained for an iron plate, which behaved like the galvanic couples under the same conditions. Inspection of the plate afterward indicated that the lower end was more seriously corroded than the upper area, presumably due to differential aeration.

If we consider the whole cell as represented in Figure 3, then

$$E_t = E_G + I(R + r) - E_x \qquad (3)$$

where R = external resistance, r = internal resistance, and E_x = the potential of the carbon electrode. If the ratio E_x/I is a straight line relation, and $(R + r)$ is constant, any change in E_G will be reflected in the composite value, E_t.

In Figure 7, the change in $E_G(\Delta E_G)$ produced by the polarizing current is also given for the iron plate in wet clay. In this case, the reference electrode was a carbon-manganese dioxide electrode. The second derivative, obtained by plotting increments of ΔE_G for each increment of 250 microamperes, emphasizes the "break" which coincides with the intersection of the graphs, representing the relation between E_t and I.

Under extremely aerated conditions, no "break" was obtained. It would appear, therefore, that incipient liberation of hydrogen is necessary to account for the accelerated rate of increase of E_G, when the iron becomes cathodic, and is favored by practically air-free conditions. Let us see why such an increase in the counter emf of polarization might be expected at this point.

When the galvanic couple becomes completely polarized cathodically, it behaves like a hydrogen electrode. Unlike metals, the potential of hydrogen depends not only upon the hydrogen ion concentration $[H^+]$, but also upon the pressure P of atomic hydrogen at the surface of the metal. In accordance with Nernst's law, any increment in potential is given by the equation

$$\Delta E_G = \frac{0.058}{n} \log_{10} \frac{\Delta P}{[H^+]} \qquad (4)$$

If $[H^+]$ is practically constant, then ΔE_G is a logarithmic function of ΔP. By Faraday's law, the rate of production of atomic hydrogen, and, therefore, also the rate of increase of P, is a linear function of current, at least initially. Consequently, ΔE_G is a logarithmic function of current, which is a characteristic of hydrogen overvoltage.[1] Any decrease in $[H^+]$, due to alkalinity at the cathode surface, would result in a further increase of E_G. A depolarizer, such as air, tending to reduce the value of P, would result in a lower value of E_G.

In addition to an expected increase in counter emf due to hydrogen, a possible increase in electrical resistance due to a hydrogen film should not be overlooked. Some evidence of this resistive component in the increase in cathodic potential is available.

The value of I_p may, therefore, be considered as equivalent to the polarizing current required to increase E_G to the level where its relation to the current is that characteristic of hydrogen overvoltage. It may be determined from the relation of the applied voltage E_t, or of the galvanic potential E_G to the polarizing current I; or by polarizing E_G to E_{Fe} provided the latter is known in the given environment.

Up to the present moment, reference has been made only to current, whereas it is current density, multiplied by time, that really controls the electrochemical processes which cause polarization. Below I_p, all external current flows to the cathode, and in the case of the iron plate, the area of the cathode was unknown. Above I_p, the external current is distributed over the surface, now entirely cathodic, not necessarily uniformly, but in accordance with the resistance and counter emf of polarization. For example, let the polarized potential, $E_c + \Delta E_c$, of the area originally cathodic be e_c, and, similarly, let the polarized potential, $E_a + \Delta E_a$, of the area originally anodic, be e_a. Then using increments, and Ohm's law

$$\frac{\Delta I_a}{\Delta I_c} = \frac{r_c(\Delta E - \Delta e_a}{r_a(\Delta E - \Delta e_c} \qquad (5)$$

where ΔE is the increment in potential applied across the couple, and r_a and r_c are the resistances of the

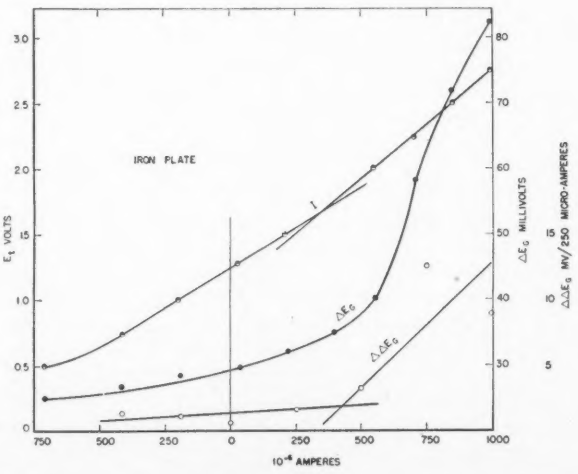

Figure 7—Correlation of observed change in potential, ΔE_G, of iron cathode with E_t/I graph.

anodic and cathodic paths, respectively. Since ΔE_a and ΔE_c are functions of ΔI_a and ΔI_c, respectively, the current density tends to be more uniform than if governed by resistance alone.[3] This is a fortunate circumstance in the application of cathodic protection.

Conclusions

The measurement of E_G by any suitable method and its relation to the polarizing current may serve to indicate the magnitude of the protective current. Under certain conditions, for example, in an air-deficient environment, this indication may be sharp. If conditions are not favorable to observance of the usual overvoltage relation to current, estimation of the protective current from polarization curves may not be practicable. Fortunately, in underground corrosion, the air-deficient environment favors the interpretation of the results of this type of measurement.

If the above relations, established in the laboratory, can be determined in the case of pipe-lines and other underground structures, it may be possible to evaluate the total galvanic current flowing in the phase boundary and, therefore, the rate of corrosion at the moment; as a corollary, it may be possible to estimate how much externally applied potential or current is required to stop corrosion. It is believed that this may be possible, in many environments, for the simpler geometrical structures where distribution of current can be accomplished.

Any discussion of this paper will appear in a Discussion Section, to be published in the June, 1951, issue of the JOURNAL.

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III. Polarization and Cathodic Protection*

Abstract

The mechanism of polarization of a galvanic couple is developed. By means of separate elements in an electric network, the roles of electrode potentials and of resistive-potential differences are demonstrated in polarization and cathodic protection. Several methods of showing the relation between polarizing current and galvanic-couple potential are discussed. The electrical conditions which determine the distribution of current flowing to a galvanic couple are defined. The use of the term "current density" in cathodic protection should be carefully qualified; otherwise, it may be meaningless.

I. Introduction

In any electrochemical process, a counter electromotive force usually results from the flow of current. This phenomenon, known as polarization, is an important retarding factor in the galvanic corrosion of metals. The usual method of studying the polarization of a galvanic cell consists of first measuring its emf with no external current flowing and then determining the potential-current relations for different currents, the latter being measured in the external circuit.

However, the electrode surfaces themselves behave like short-circuited galvanic cells with internal currents not subject to direct measurement, and the polarization thereon affects the electrode potentials. Although polarization opposes these currents, they cannot be extinguished entirely by self-polarization, because the latter requires some current to maintain it. They may, however, be reduced to zero by increasing the polarization through the application of external current. This is the mechanism of stopping galvanic corrosion by cathodic protection.

It is the purpose of this paper to relate the behavior of a galvanic couple toward external current to the problem of ascertaining when cathodic protection is accomplished.

II. Behavior of a Galvanic Couple Toward Applied Current

Let a galvanic couple G, consisting of an anode A and cathode C, be joined electrically to an auxiliary electrode X in the same electrolyte. When X is cathodic to G, external current I will flow in the direction indicated in Figure 1. The total current from the anodic area A will then be $I + i$, where i is the internal current within the galvanic couple. Any increase in polarization at the anode, caused by the higher current density resulting from I, reduces the magnitude of i. Such a reduction in i, caused by increased polarization, has been called the "difference effect."[1]

In accordance with Faraday's law,

$$W = (I + i)kt \qquad (I)$$

where W = weight of metal dissolved, k = electrochemical equivalent, and t = time.

Since i is not included in the meter reading, which indicates I only, the total anodic weight-loss represented by equation (I) may be greater than that equivalent to the observed current. The apparent current efficiency is then over 100 percent. If, through the "difference effect," i becomes zero, the measured current I will represent the true rate of metal dissolution.

When X is anodic to G the current pattern will be that shown in Figure 2, where the total current flowing to cathode C is $I + i$. Any increased polarization, at the cathode, resulting from the larger cathodic current, opposes the internal current i. Any reduction in i, resulting from this increased cathodic polarization, is called "cathodic protection." If this effect is great enough to reduce i to zero, the loss of

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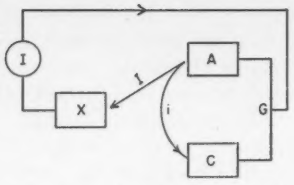

Figure 1—Path of current *I* when *X* is cathodic to couple *G* in same electrolyte.

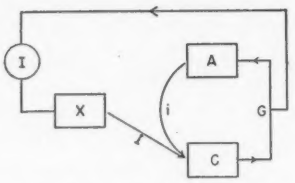

Figure 2—Path of current *I* when *X* is anodic to couple *G* in same electrolyte.

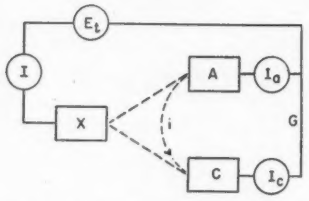

Figure 3—Path of current *I* depends on relation, $E_t = E_G - e_x$.

metal on the anodic area due to galvanic corrosion is completely stopped.

Now let an external emf E_t be introduced (Figure 3). If E_t is adjusted until $I = 0$, then $E_t = (E_G - e_x)$. If E_t is increased, then

$$E_t = (E_G - e_x) + IR_t \qquad \text{(II)}$$

where E_G = the potential of the galvanic couple, e_x = the potential of the auxiliary electrode, and R_t = the total resistance in the circuit.

If we vary the magnitude and direction of E_t, and simultaneously measure I_a, I_c, and I we obtain the three polarization curves shown in Figure 4, one for anode A, one for cathode C, and one for couple G, respectively. These relations are fundamental in the study of cathodic protection. For example, complete cathodic protection is achieved when anodic current $I_a = 0$. The applied current required to do this is I_p and the total polarization (emf + ir) of the cathode is

$$\Delta E_c + I_p \cdot r_c$$

where r_c = the resistance of the cathodic path of current I_p and ΔE_c = emf of polarization. The condition for cathodic protection as defined by Mears and Brown[2] is then

$$E_c + \Delta E_c + I_p \cdot r_c = E_a \qquad \text{(III)}$$

which means that the polarized potential of the cathodic area is equal to the open-circuit potential of the anodic area. The value of E_a here depends upon the environment created by the flow of current until a steady state exists.

III. Determination of "Protective Current" and "Protective Potential"

The logical approach to this problem is the correlation of the causative factor E_t with any measurable effects which are related to the reduction of i to zero. Among these are changes in ikt, E_G, and I. The determination of the rate, or extent of corrosion, by weight-loss (ikt) is seldom practicable except on small test-specimens. The measurement of E_G may serve as a criterion for cathodic protection if its relation to E_a is already known for the given environment. Any change in the relation of E_G or E_t to I, occurring at I_p, may also be used as criteria of complete cathodic protection.

In equation (II) it may be seen that any change in E_G will be reflected in E_t. Therefore, if attainment of I_p is accompanied by an increment in E_G, a corresponding inflection in the E_t/I curve, as well as the E_G/I curve, will indicate cathodic protection. If conditions are favorable, we then have the possibility of at least four electrical criteria of cathodic protection: first, the relation of E_G to E_a, if the latter is known; second, an inflection in the E_G/I curve; third, a corresponding inflection in the E_t/I curve; fourth, any relation of E_G to I, at I_p, indicating hydrogen overvoltage.

The measurement of E_G has been described in Part I.[3] When the reference electrode E_s is introduced in Figure 5, the resistive components, Ir_s and IR_G, are deducted by balancing the Wheatstone bridge. Then the emf $(E_G - E_s)$ is observed as $2V_g$, where

$$E_G = e_a - i_o r_a \qquad \text{(IVa)}$$

$$= e_c + i_o r_c \qquad \text{(IVb)}$$

and

$$i_o = \frac{e_a - e_c}{r_a + r_c} \qquad \text{(V)}$$

IV. Elementary Relations in Application of Cathodic Protection

For the purpose of illustration, the electrode potentials of several metals in wet clay are given in Table I, as measured with a high-resistance potentiometer using the carbon-manganese dioxide electrode as reference. Although no external current was flowing to or from these metals during measurement, the observed potentials must not be considered values of E_a. Due to local galvanic currents on their surfaces, the potentials observed were really some mean value of the galvanic couple potentials E_G, being somewhere between the polarized potentials of the local anodes and cathodes. The tabulated values must, therefore, not be considered accurately reproducible, since they depend upon the particular status of the galvanic couples at the moment of measurement. The open-circuit potential E_a might have been observed for each metal if it had been cathodically polarized just the right amount, that is, until the condition in equation (III) is met. The problem of determining this "right amount" is the basic problem of cathodic protection.

If we assemble a galvanic couple of iron and copper, using meters to measure the currents as indi-

cated in Figure 3, we find that in order to prevent galvanic current flowing between the two metals, they must be brought to the same potential. This may be accomplished by polarizing one of the metals, as for example, by passing current to the copper from some auxiliary anode as carbon, until the polarized potential of copper becomes —1.26 volts, which is that of iron under the given environment. This is the result of electrochemical action at the phase boundary of copper caused by cathodic current × time, or coulombs.

It should be fully realized that the polarized potential is the result of a change in environment produced by the current, the metal itself remaining unchanged.

It is informative to consider the difference in the magnitude of E_t required to drive current from carbon to copper before, and after, it is joined to iron. The emf of the carbon/copper cell is

$$e_x - (-0.56) = e_x + 0.56.$$

Before joining, current will begin to flow to copper when

$$E_t > e_x + 0.56.$$

After joining, current will begin to flow to the copper when

$$E_t > e_x - E_G$$

where E_G is somewhere between —0.56 and —1.26; and as E_t is gradually increased, current flows to copper because its potential is exceeded first. On further increasing E_t, the increased current to the copper polarizes the copper until its potential $e_c + I_c \cdot r_c$ becomes equal to that of the iron. Then current flows to the iron also; that is, when

$$E_t > e_x + 1.26$$

where $e_x + 1.26$ is the emf of the carbon/iron cell.

One might imagine E_G as a potential "barrier" or "hurdle," which must be exceeded by E_t before the current "spills over" to the copper, the barrier being there by virtue of its contact with iron. If current flows to the iron for a period of time, its potential shifts to higher values as a result of higher alkalinity. When the pH reaches a value of about 9.5 the emf of the iron-hydrogen cell becomes zero and the galvanic corrosion of iron is stopped. The open-circuit potential of iron is then E_a.

TABLE I.

Observed potentials of several metals in wet clay referred to the carbon-manganese dioxide electrode.

Metal	Volts
Magnesium	—2.08
Zinc	—1.57
Aluminum	—1.27
Iron	—1.26
Lead	—1.02
Nickel	—0.63
Copper	—0.56
Carbon-manganese dioxide	0.00

In studying polarization effects, we have a choice between controlling current and observing variations in potential or controlling potential and observing variations in current, known as the "constant current" or "constant potential" methods, respectively. Since current-density × time is the immediate cause of polarization, it should be the controlled variable if known. This, however, is rarely the case and in cathodic protection is almost meaningless because of unknown current distribution. For example, the current density at edges or nearby areas may be an order of magnitude greater than on more remote areas. If current is kept constant by the usual practice of maintaining a high resistance and a high applied-voltage in the circuit to reduce the effect of any variations in emf, the purpose of the experiment is largely defeated, because it is the relation between current and any variation in counter emf which we wish to determine.

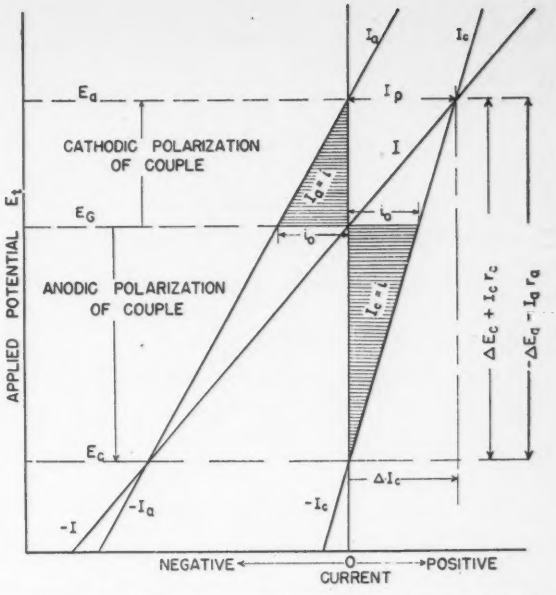

Figure 4—Three polarization curves showing relation of I_a, I_c and I to E_t.

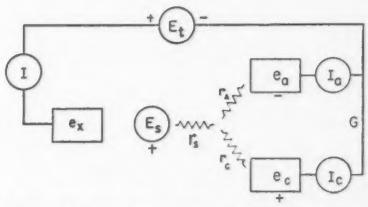

Figure 5—Introduction of reference electrode S for measuring E_G.

Consequently, if we reduce the resistance in the circuit to a minimum and keep the applied potential constant, any change in current resulting from counter emf may be significant. For this reason, the "constant potential," or polarographic method, is preferred. The relation between E_t and I may be as informative as the relation between E_G and I. The technique is, therefore, one of maintaining potential, and allowing current to adjust itself in accordance with the counter emf and with Ohm's law.

In Figure 4 it is shown that the direction of the currents through a galvanic couple are determined by the magnitude and direction of the applied emf

E_t. The importance of E_t becomes apparent if we refer to Figure 5 again and write the equations for the two-mesh network.

Proceeding clockwise, we have

$$E_t - (e_a - e_x) - Ir_s - I_a r_a = 0 \qquad \text{(VI)}$$

and

$$(e_a - e_c) - I_c r_c + I_a r_a = 0. \qquad \text{(VII)}$$

Rearranging for the use of determinants,

$$-I_a r_a = -E_t - (e_a - e_x) - Ir_s \qquad \text{(VIII)}$$

and

$$I_a r_a - I_c r_c = -(e_a - e_c). \qquad \text{(IX)}$$

Expansion of determinants and simplification then gives

$$\frac{I_a}{I_c} = \frac{E_t - Ir_s - (e_a - e_x)}{r_a} \cdot \frac{r_c}{E_t - Ir_s - (e_c - e_x)} \qquad \text{(X)}$$

If we let E = the potential applied across the couple, then

$$E = E_t - Ir_s + e_x$$

and

$$\frac{I_a}{I_c} = \frac{(E - e_a)}{r_a} \cdot \frac{r_c}{(E - e_c)} \qquad \text{(XI)}$$

This relation defines the magnitude and direction of I_a and I_c. For example, if $E < e_a$, I_a is negative, which means that current is flowing from the anode to the electrolyte. If $E = e_a$, $I_a = 0$, which means that cathodic protection is achieved. If $E > e_a$, I_a is positive and current is flowing to the area, initially anodic.

This equation of current partition may be used as an electrode potential criterion for cathodic protection, which is achieved when $E = e_a$. This equality should be written $E = E_a$, since the requirement of Mears and Brown still holds. Then since E also equals $E_G + IR_G$, $E_a = E_G + IR_G$ for cathodic protection.

V. Partition of Current in Galvanic Couples

In order to demonstrate some of these relations for iron-hydrogen couples, a simple cell was set up (Figure 6) in a Lucite box containing clay which was kept wet by maintaining a water-level as indicated. The couple elements of equal apparent areas were 5/16-inch (0.79 cm) rods, about 1 inch (2.5 cm) apart, extending 4¾ (11 cm) inches into the clay. The auxiliary electrode was a graphite rod dipping in the water in an alundum tube about 11 inches (28 cm) from the rods. The reference electrode was a manganese-dioxide-carbon element of a specially prepared dry cell, containing zinc chloride and calcium chloride solution. This element was sealed into a Lucite tube, having a cotton canvas diaphragm-bottom, moistened with calcium chloride to make electrolytic contact with the clay. Comparison of this element with a second one standing by indicated it to be sufficiently near constancy for the purpose. It had been made for field use and was used here because of convenience. The surface of the clay was covered with a ¼-inch (0.64 cm) layer of sand and the sand was covered with about the same depth of paraffin to minimize evaporation. The galvanic cell was, therefore, exposed to very moist and poorly aerated conditions.

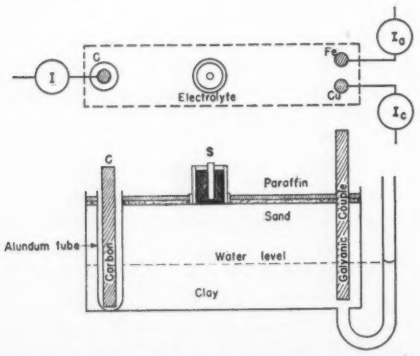

Figure 6—Laboratory cell for making measurements on a galvanic couple.

The wet clay practically eliminated convection in the electrolyte and was, therefore, conducive to reproducibility of results. The maintenance of the phase boundary was the result of the effects of current density and of diffusion processes, including that of air downward and moisture upward, providing conditions for a differential aeration cell. To some extent, therefore, the rate of corrosion may be said to have been largely "diffusion controlled."

In order to obtain values for r_s, r_a, and r_c (Figure 5) the composite resistances X_1, X_2, and X_3 were measured according to the method in Part I[3] where

$$X_1 = r_s + r_a$$
$$X_2 = r_s + r_c$$
$$X_3 = r_s + R_G$$

and

$$R_G = \frac{r_a r_c}{r_a + r_c}.$$

By the use of quadratic formulas, the separate path resistances were calculated.

Polarization curves for iron and copper separately, and for the Fe/Cu couple, are given (Figure 7). The effect of time on the potential of the copper cathode, which is actually a hydrogen electrode, is shown by the three curves, the dotted one being arbitrarily selected to represent the values of $e_c + I_c r_c$ during polarization of the couple. At a current of 860 μa the polarized potential of copper (hydrogen electrode) is equal to that of iron. The potential E_G is so near that of iron, since the cathodic polarization of copper is much greater than the anodic polarization of iron.

In accordance with the relations expressed in equation (XI) and using increments,

$$\frac{\Delta E - \Delta e_A}{r_a} = \Delta I_a \text{ and } \frac{\Delta E - \Delta e_c}{r_c} = \Delta I_c \qquad \text{(XII)}$$

where the emf-difference ratio,

$$\frac{\Delta E - \Delta e_a}{\Delta E - \Delta e_c}, \text{ not } \frac{r_c}{r_a} \text{ alone,}$$

is an important relation in determining the current ratio.

Since

$$\frac{E - E_G}{R_G} = I \qquad \text{(XIII)}$$

$\Delta E = \Delta E_G + R_G \Delta I$, and so ΔE may be computed from the experimental data. Then Δe_a and Δe_c may be obtained from equation (XII). Numerically of course, the above emf-difference ratio is also equal to the ratio of the respective resistive components, $\frac{\Delta I_a r_a}{\Delta I_c r_c}$.

If the increments in counter emfs, Δe_a and Δe_c, should become equal, then the emf-difference ratio will become unity and, at this moment, the current ratio $\Delta I_a/\Delta I_c$ is equal to the resistance ratio r_c/r_a.

Similar curves were obtained for an iron-magnetite couple arranged in the same manner (Figure 3) as for the iron-copper couple. The magnetite element was prepared by heating a 5/16-inch (0.76 cm) iron rod at 1020° F (550°C) two hours to give an adherent oxide coating. The readings on the Fe/Fe_3O_4 couple are given in Table II as obtained in accordance with the relations in Figure 4.

The values of r_a and r_c included meter resistances of 18.6 ohms. The direction of I_a reversed when the external current was 353 μa and $E_G - E_s$ was 1216 mv. This was the result of the iron and magnetite reaching the same potential. Above this potential, current flowed to both iron and magnetite. The increments in potentials and currents are given in Tables IV and V for different potential levels represented by E_t, after I_a became positive.

If the partition of current between the paths were governed by resistance alone, then $\Delta I_a/\Delta I_c$ should equal r_c/r_a or 1.6. However, as is apparent in column 5, Table IV, $\Delta I_a/\Delta I_c$ varies from 10 to 3.1. Hence some other factor must be dominant.

The emf-difference ratio, given in column 7, Table V when multiplied by the resistance ratio, 1.6, gives the actual partition ratio, column 5, Table IV. The

TABLE II.

Readings on an iron-magnetite couple in wet clay. Auxiliary electrode, graphite.

E	I	I_a	I_C	$\frac{E_G - E_s}{1200} + mv$
volts	μa	μa	μa	mv
0	—404	—715	+311	0
0.25	—217	—535	318	4
0.50	— 45	—375	330	7
0.75	+125	—215	340	10
1.00	262	— 80	342	14
1.14	353	0	353	16
1.25	430	+ 70	360	19
1.50	568	195	373	25
1.75	675	290	385	32
2.00	765	370	395	39
2.25	867	450	417	47
2.50	940	505	435	55

TABLE III.

Measured Resistances

Resistance	Ohms
r_a	16
r_a	24.6 (including meter)
r_c	4.0 (" ")
meter	18.6 in each path
R_G	15.2

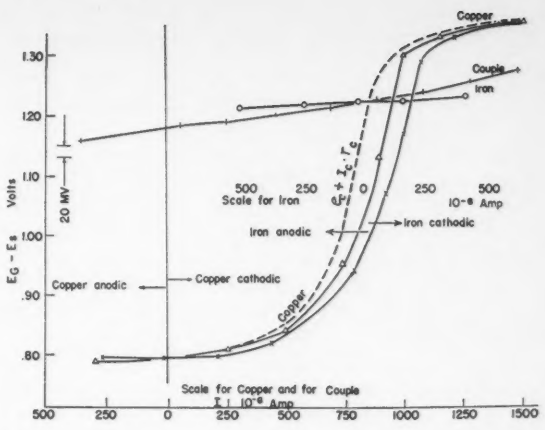

Figure 7—Polarization curves for copper, iron, and an iron-copper couple.

smaller increment in current through the cathodic path is, therefore, not due to its higher resistance r_c alone, but mainly to the higher counter emf e_C in that path.

The relation expressed in equation (XI) has wide application in cells where current is flowing to cathodic areas in parallel. In electroplating, it is concerned with determining the "throwing power" of the electrolyte, whereby current is diverted from the nearer areas of high current density to the farther areas of lower current density. Likewise in cathodic protection, the current tends to spread out from areas of greater polarization to the surrounding areas. Thus, polarization favors the required distribution of the protective current. Since partition of current is governed by the relation in equation (XI) the term current density, as applied to the whole couple, has an indefinite meaning. For example, while E_t was being increased from 1.25 to 2.50 volts, the total current I increase from 353 to 940 μa. Of this increase

TABLE IV.

Increments in readings for iron-magnetite couple after I_a reverses.

1	2	3	4	5	6	7
E_t	ΔI	ΔI_a	ΔI_c	$\Delta I_a/\Delta I_c$	ΔE_G	$R_G\Delta$
volts	μa	μa	μa		mv	mv
1.25	77	70	7	10	3	1.17
1.50	138	125	13	9.6	6	2.10
1.75	107	95	12	7.9	7	1.60
2.00	90	80	10	8.0	7	1.37
2.25	102	80	22	3.6	8	1.55
2.50	73	55	18	3.1	8	1.11

TABLE V.

Increments in computed values of iron-magnetite couple after I_a reverses.

1	2	3	4	5	6	7
E_t	ΔE	$\Delta I_a r_a$	$\Delta I_c r_c$	Δe_a	Δe_c	$\frac{\Delta E - \Delta e_a}{\Delta E - \Delta e_c}$
volts	mv	mv	mv	mv	mv	
1.25	4.2	1.7	0.3	2.5	3.9	5.7
1.50	8.1	3.1	0.5	5.0	7.6	6.2
1.75	8.6	2.3	0.5	6.3	8.1	4.6
2.00	8.4	2.0	0.4	6.4	8.0	5.0
2.25	9.6	2.0	0.9	7.6	8.7	2.2
2.50	9.1	1.4	0.7	7.7	8.4	2.0

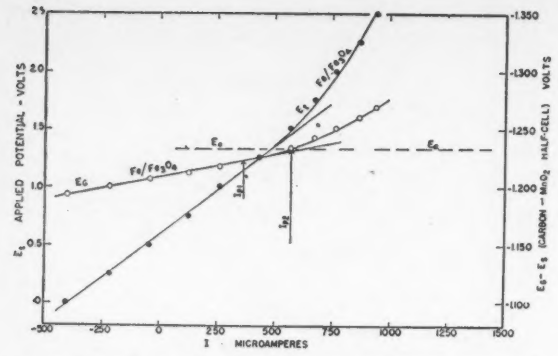

Figure 8—Relation of protective currents to polarization curves for iron-magnetite couple.

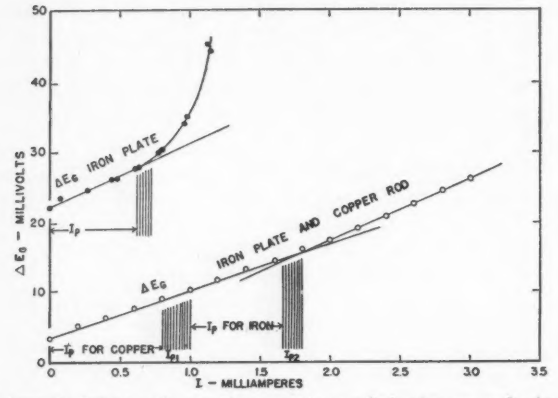

Figure 9—Relation of protective currents to polarization curves for iron plate.

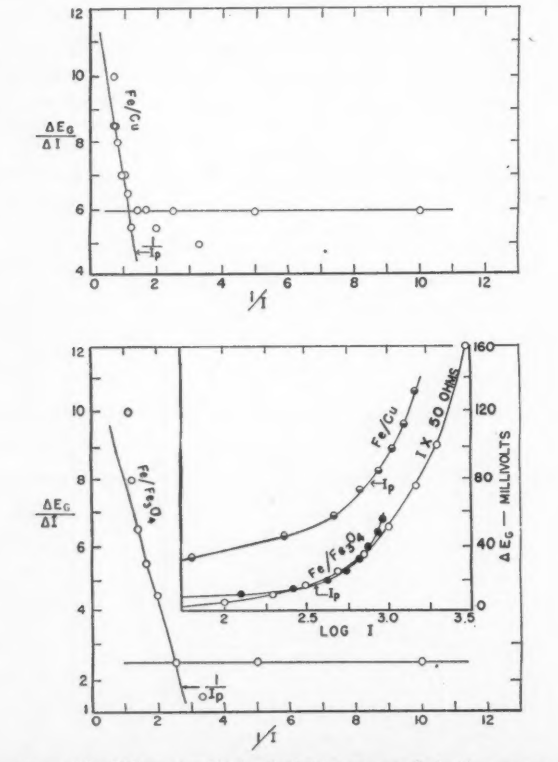

Figure 10—Different methods of plotting some polarization curves.

of 587 μa, current on the magnetite increased 82 while that on the iron increased 505 μa. Current to the area initially anodic is unnecessary, since it is the current density I_c/d on the cathode which is providing the protection, where d = the usually unknown area of the cathode.

The relations in equation (XI) may also be expressed in such a way as to make resistance and polarization additive. For example, since

$$\Delta I_a = \frac{\Delta E - \Delta e_a}{a_a} \text{ and } \Delta I_c = \frac{\Delta E - \Delta e_c}{r_c}$$

then

$$\Delta E = I_a r_a + \Delta e_a \text{ or } \frac{\Delta E}{\Delta I_a} = r_a + \frac{\Delta e_a}{\Delta I_a}$$

and

$$\Delta E = \Delta I_c r_c + \Delta e_c \text{ or } \frac{\Delta E}{\Delta I_c} = r_c + \frac{\Delta e_c}{\Delta I_c}.$$

By elimination of ΔE we have

$$\frac{\Delta I_a}{\Delta I_c} = \frac{r_c + \Delta e_c/\Delta I_c}{r_a + \Delta e_a/\Delta I_a} \qquad \text{(XIV)}$$

where $\frac{\Delta e_c}{\Delta I_c}$ and $\frac{\Delta e_a}{\Delta I_c}$ represent the rates of change of the emf of polarization with current. This expression, however, does not show the relation of the important term E to current partition.

VI. Possible Relations of E_G and E_t to I_p

In Figure 8, both the values of E_G and of E_t are plotted against the external current I for the Fe/Fe_3O_4 couple. It is apparent that the value of I_{p1} is reached at a potential slightly below E_a, the open-circuit potential of iron. The reason for this apparent discrepancy is probably as follows: When the potential of magnetite becomes equal to that of the iron, the value of I_a becomes zero. However, the iron itself behaves like a galvanic couple, so that a still larger current I_{p2} is necessary to polarize the cathodic areas of the iron, as well as the magnetite to the open-circuit potential E_a of iron. In this respect, the use of separate galvanic elements, to include meters, has its limitation in studying cathodic protection, unless the anodic element has a very small area. Another reason for E_G being below E_a at I_{p1} is that $E_G < E_a$ by the amount $I_p \cdot R_G$ when cathodic protection is complete.

When the anodic area is large, as in Figure 9, where an iron plate, 2 x 6 inches (5.1 x 15 cm), is joined to the same copper rod used above, we have I_{p1} required to polarize the copper to the potential of the iron plate, and then I_{p2} required to polarize both iron plate and copper to the open-circuit potential of iron. It is apparent that the use of the term "current density" for cathodic protection must be qualified. For example, the value of $I_p/30$ cm² for copper is about 3.3 ma/dm²; and $I_p/155$ for iron is about 0.45 ma/dm, assuming uniform current distribution.

As indicated in Figure 8, the change in relation of E_t to E_a is distinct. The accelerated rise in E_G, which occurs probably because of the beginning of liberation of hydrogen on the formerly anodic area, is reflected in E_t. Any error of measurement, due to IR

potential drops, is avoided here, since the increment in E_G manifests itself directly. If a nonpolarizable auxiliary anode is on hand, or if the polarization of the anode is linear, this is an accurate method of observing any change in E_G.

The conditions for cathodic proteciton are graphically summarized in Figure 11 where (A) shows the relations for I below cathodic protection; (B) for I at cathodic protection; and (C) for I above cathodic protection.

VII. Methods of Interpretation of Relation of E_G to I

Assuming the validity of the usual overvoltage relation

$$E_G = a + b \log I \qquad (XV)$$

where 'a' and 'b' are constants, E_G may be plotted against log I as in Figure 10, and the values of I_p are indicated, for the iron-copper and iron-magnetite couples. Obviously, there are no inflections in these logarithmic curves corresponding to I_p. Such curves are, therefore, of limited use in determining I_p, unless excessive currents are used for the customary testing and extrapolation of the straight-line portions of the curves to their intersections if there are any such linear portions. Another disturbing feature of the E_G/log I curve is its similiarity in some cases to a log IR curve. For example, in Figure 10, IR is plotted against log I for a resistance of 50 ohms giving a curve which is almost coincident with the E_G/log I curve for the iron-magnetite couple. It seems evident, therefore, that the shape alone is not sufficient proof that we are dealing with a hydrogen overvoltage curve.

If, however, we differentiate equation (XV), we obtain,

$$\frac{dE_G}{dI} = b/I \qquad (XVI)$$

which is also plotted in Figure 10 for both couples. If the potential-current relation were that of a resistance, then the plotting of $\frac{dE_G}{dI}$ against the reciprocal of I would give a horizontal line. The two intersecting lines leave no doubt that the relation is other than an IR drop, and the intersection corresponds closely to the values of $1/I_p$ for both couples. The curves shown in Figure 10 for the polarization of galvanic couples suggest that the usual hydrogen overvoltage relations for different metals really represent the same phenomenon, that is, the polarization of galvanic cells on their surfaces. For example, the value of I_p corresponds to the minimum current required to liberate hydrogen, the potential for currents above I_p being the overvoltage.

VIII. Effect of Aeration

The couples used in these experiments were poorly aerated and this was an important factor in the results obtained. Since the polarization, and more especially its acceleration soon after the applied current reached I_p, was evidence of incipient hydrogen, any increased aeration should have an adverse effect, and this was found to be the case.

Excessive aeration of the iron completely removed such evidence of cathodic protection from the polarization curves. In this case, cathodic protection depends less upon the emf of polarization and to a larger extent on the resistive component of polarization. As a result, a very high value of I_p may be required. If the emf component of polarization is too low, cathodic protection may not be practicable.

Since underground corrosion is usually most severe under conditions of very limited aeration, it is fortunate that, under these same conditions, polarization curves may better serve as criteria for determining the cathodic protection. Correlation of results of measurements in the field with corrosion rates is necessary to determine whether such polarization

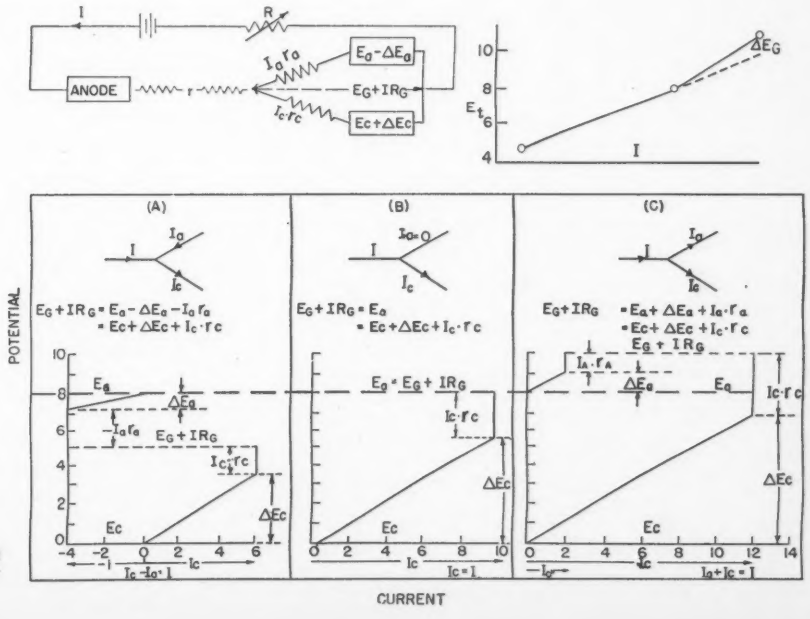

Figure 11—Conditions preceding (A) and after (C) cathodic protection obtained in (B).

curves can be so interpreted. Even in a deaerated environment the success of cathodic protection may depend very largely upon the emf of polarization, as reflected in the measured values of E_G.

Conclusions

Under laboratory conditions of restricted aeration in wet clay, polarization of an iron-hydrogen couple by an applied current may be used to evaluate the internal current and, therefore, also the applied potential and current required for the cathodic protection of iron. The importance of phase-boundary resistances in polarization measurements is demonstrated. Methods of interpreting polarization curves and their relation to cathodic protection are described.

The application of these principles to cathodic protection when the ratio of cathodic area to anodic area is very large and the full importance of the principle of current partition to current distribution should be studied for long distances underground. The criterion of cathodic protection based on applied potential may be useful, particularly where the open-circuit anode potential may vary with conditions and with time. Application of the required constant potential, the applied current adapting itself to that necessary to maintain the constant potential, should result in economy of power.

An explanation of hydrogen overvoltage on the basis of polarization of galvanic couples in the phase-boundary is suggested. A practical criterion for determining the current, or potential, required for cathodic protection, in the poorly aerated conditions underground, may require detection of the usual hydrogen overvoltage relation, such as that in equation (XVI) and Figure 10.

Any discussion of this paper will appear in a Discussion Section, to be published in the June 1951 issue of the JOURNAL.

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Discussions

The Use of Cathodic Protection in Conjunction With Paint Coatings—A Progress Report. By W. L. Crosby. *Corrosion*, **6**, No. 11, 383-388 (1950) Nov.

Discussion by E. C. Reichard, Research Metallurgist, American Smelting and Refining Co., Barber, N. J.: One of the objects of Mr. Crosby's interesting paper was to stimulate discussion that might be used as a basis for further investigations. Accordingly the following comments are submitted.

Mr. Crosby states that corrosion of transformer cases has been satisfactorily controlled by means of magnesium anodes. It is further stated that paint stripping has occurred and it is desired to minimize this effect. While a study of various paint systems is warranted I would like to inquire if Mr. Crosby's experience doesn't indicate over-protection and that anode current outputs could be readily controlled to lower and safer levels by means of resistors?

Mr. Crosby titles a phase of his work as a report on the effect of cathodic currents on various paint coating systems. I believe that this wording should be restated to indicate that the effect of excessive cathodic currents on paints had been studied.

The initial cathodic currents reported in the tests ranged from 32 to 83 milliamperes. These currents were impressed on shot-blasted cathode areas of which only one, of a total of fifteen square inches was left unpainted or bare. Thus, current densities on this exposed one square inch of cathode surface, at the start of the test, ranged from 4,600 to 12,000 milliamperes per square foot!

In later tests, effects of controlled current densities of 0.5 and 1.0 milliamperes were studied. These values are equivalent to 72 and 144 milliamperes per square foot on the one square inch of bare shot-blasted cathode area. Accordingly I feel we should consider this report as a study of the effect of excessive cathodic currents on paint coatings.

This is another item: In the "lower current test" in which effects of cathode current densities of from 72 to 144 milliamperes per square foot were studied, Mr. Crosby states that rusting was obtained. It is stated that the samples in this test were lifted from the solution and hung in room air for a period of four hours each working day.

It should be emphasized that during this four hour drying period the specimens were not subjected to any cathodic protection although they were undoubtedly wet for a large portion of the four hour period. A gradual, rather than a sudden lowering of the water level is generally obtained in practice. Thus, surfaces would be subjected to protective cathodic current and potential effects while drying.

Additional study of current density and exposure characteristics more nearly approaching engineered conditions should result in the development of very informative and valuable data.

Comment by Oliver Osborn, Texas Division, The Dow Chemical Co., Freeport, Texas:

In response to a statement made to the effect that the current output from magnesium was too great to be used for supplying cathodic protection in conjunction with protective coatings, we should like to point out that there are a number of methods available for controlling magnesium current output to any desired value. Of course in a considerable percentage of cases, water resistivities are high enough to eliminate this problem. However, in very low resistivity media one of the simplest solutions is to adjust the anode to cathode surface area ratio to such a value that the desired current density is obtained. Should this procedure produce too short an anode life, another method may be employed in which larger anodes are used and electrical resistors are placed in the circuit to restrict the current to an optimum value.

The work of The Dow Chemical Company in this field can also only be presented as a "Progress Report," since the brief period in which tests have been under way will not permit the drawing of concrete conclusions.

Indications to date, however, are as follows:

1. The detrimental effect of cathodic protection on protective coatings has been confirmed in only one field application; however, results to the contrary have been obtained in a number of cases. In two field applications, one of 45 months duration, coatings are still in excellent condition, and in a 100-day laboratory seal test on eight different coatings cathodic protection appears to be actually increasing the protective value of the coating.
2. Fresh waters are less destructive to coatings than highly mineralized waters.

Table I will summarize field tests conducted to date.

TABLE I

Field Tests—Effect of Cathodic Protection With Magnesium on Portective Coatings

Type of Equipment	Media	Type of Coating	Duration of Test	Condition of Coating
1. Elevated Water Tower	Fresh H_2O (600 ohm/cc)	Water Emulsion Asphalt	45 Mos.	Excellent
2. Tanker Bilge Compartment	Seawater	Water Emulsion Coal Tar	5.0 Mos.	Excessive Breakdown
3. Steel Hull Marine Tractor	Seawater	Vinyl	11 Mos.	Excellent

One series of laboratory tests was conducted as follows: Coatings consisting of four types of coal tars (2 of which were also felt wrapped) and four types of vinyls were applied to 1½-inch x 14-inch pipe sections and then submerged in vats containing circulating sea water. The layout is shown in Figure 1. Cathodic protection from a magnesium anode was then applied to one-half of the specimens and the other one-half were allowed to remain unprotected. Currents on the protected specimens were adjusted to maintain a Cu $CuSO_4$ potential of 1.10 volts.

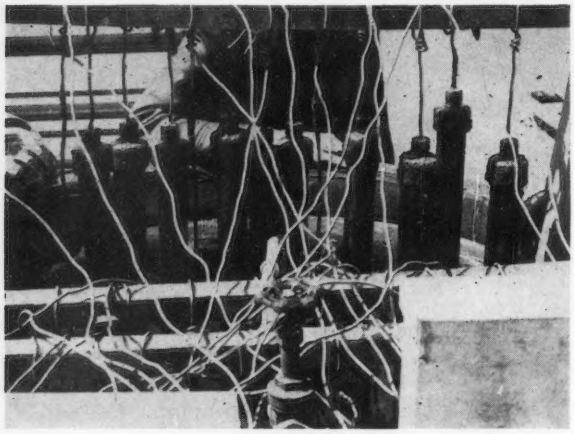


Figure 1

In order to determine the change in condition of coatings with time, weekly electrical resistivity readings were made on all specimens. By comparing this change of the protected and unprotected specimens an evaluation of the effect of cathodic protection was obtained. Figure 2 will show that after 92 days cathodic protection has had a beneficial effect. Protected coal tar specimens have actually increased in resistance and protected vinyl specimens have decreased in resistance, but at a lesser rate than those which were unprotected. It is not yet possible to predict whether the above action will persist with time. Cathodic protection may continue to seal all voids; on the other hand when breaks of considerable size occur, sufficient current may then flow to cause spalling of the coating next to the break.

The magnitude of applied current to maintain a copper copper sulfate potential of 1.1 volts was greatly different from Mr. Crosby's value. Where some of his applied currents were as high as 300 mils per square foot, the highest value in our case was in the order of 0.2. This could explain the widely different results obtained.

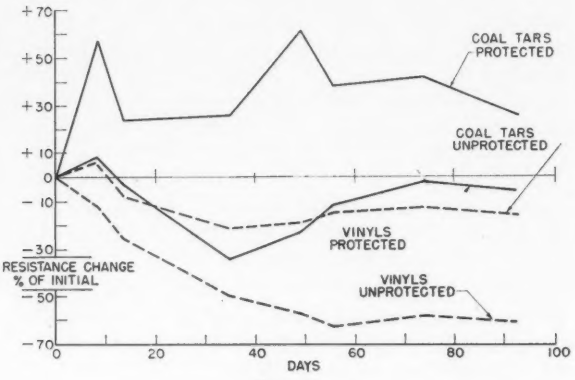


Figure 2

Some Factors Affecting Paint Performance On Cathodically Protected Steel*

By ARNOLD J. EICKHOFF* and DAVID L. HAWKE*

RATHER THAN TRY to discuss Mr. Crosby's paper we would prefer to just touch on some of the theoretical considerations of paint and cathodic protection and present some results of our laboratory work.

The idea that cathodic protection might be of use in protecting metallic structures was promoted approximately 125 years ago. At that time paint was not part of the picture. With the increasing cost of replacing steel structures—especially in inaccessible areas, some method of protecting them is extremely desirable. Mr. Crosby has very ably pointed out how paint and cathodic protection may be combined to protect transformers.

By the use of a paint coating on the structure, the protective current requirements can be drastically reduced. Hence economic considerations dictate that we examine organic coatings. One of the important questions is "What inherent characteristics should the paint film possess?" The work described in this discussion is intended to supply a partial answer.

Some of the factors which may be expected to affect the performance of paint on cathodically protected steel are:

1) Deteriorating effect of the products of electrolysis, notably alkali at the cathode.
2) Migration of water through the paint film under electroosmotic forces.

★ A discussion on the paper by W. L. Crosby, "The Use of Cathodic Protection in Conjunction with Paint Coatings—A Progress Report." Published in CORROSION, Vol. 6, No. 11, 383-388 (1950) Nov. Presented by Arnold J. Eickhoff at the Sixth Annual Conference, National Association of Corrosion Engineers, St. Louis, Mo., April 4-7, 1950.

* National Lead Company Research Laboratories, 105 York St., Brooklyn, N. Y.

Products of Electrolysis

The most significant factor in this respect is the increasing alkalinity of the solution in the vicinity of the cathode. The accumulation of sodium hydroxide and accompanying electrolysis effects at a painted steel cathode immersed in a sodium chloride solution can be a potent factor working toward destruction of the paint film. This destructive action is unfortunately damaging under those conditions when cathodic protection is most needed; i.e.

a) When a holiday in the paint coating permits contact of electrolyte with bare metal at a small area. The high local cathode current density resulting when voltage is applied may permit attack and lifting of the paint by alkali spreading out from the holiday.
b) When thorough soaking of the paint by the electrolyte has occurred and indications are obtained that initiation or increase of protective current is required for protection of the structure. Accumulation of alkali between the metal and the paint film where its diffusion away is highly restricted could then destroy the bond which may already be weakened, and eliminate the remaining protective value of the paint.

The evolution of hydrogen gas at the cathode, if conditions permit, might also contribute to deterioration of the paint by blister formation.

Under some circumstances the products of electrolysis at the anode might be destructive toward a paint film. However these would not generally contact the paint in sufficient concentration to cause trouble except under unusual circumstances where the anode might be close to the painted surface and in a limited volume of solution where diffusion was restricted. Possible anodic electrolysis products which might be detrimental are chloride, oxygen, or certain acids whose anions might be present in the electrolyte.

Electro-Osmotic Effects

Electro-osmosis, defined as the migration of water or other liquid through a porous membrane under the influence of an electrical potential gradient, must also be considered where paint is to be used in conjunction with cathodic protection. The occurrence of this effect depends upon the fact that when a liquid is in contact with a solid phase, represented by a porous diaphragm, the two phases acquire unlike charges giving rise to a potential difference between them. Since the liquid is free to move, it tends to migrate under the influence of an electric field.

Because most substances develop a negative charge when in contact with water, the water itself, positively charged, is drawn toward the cathode. The rate of flow of water under electro-osmosis varies directly with the current, other factors being equal. Among the other factors which affect the rate of flow are the nature of the diaphragm, nature and amount of dissolved substances in the water, and temperature.

The relative importance of alkali formation and electro-osmosis, as contributors to paint failure, have not been established but would be expected to vary with the paint and exposure conditions.

In the preliminary laboratory study, described here, no attempt was made to evaluate the rate of electro-osmosis, the principal object being to establish, if possible, a general correlation between alkali resistance and paint performance in the presence of cathodic protection. It is believed that the presence of a bare metal window on each panel permits some distinction to be made between failures due to the two effects. Loss of adhesion and lifting originating at the bare steel-paint junction was likely to be caused primarily by alkali attack. Blistering, occurring at areas remote from the window, would probably involve electro-osmosis as well as attack by diffusing alkali.

Types of Paints

In this study five types of pigmented vehicles were studied under varied conditions of protective current flow.

The vehicles were:

1) Linseed oil
2) Alkyd resin
3) Modified chlorinated rubber resin
4) Air dried vinyl resin
5) Baked vinyl resin

The above vehicles were chosen because of their generally recognized differences in alkali resistance. Elementary electrochemistry indicates that the passage of direct current through a sodium chloride solution results in the formation of sodium hydroxide at the cathodic areas. In this case there were "windows" in the paint film or bare steel areas. Hence sodium hydroxide was formed at the water-metal-paint film junction. Under certain conditions chlorine was formed at the anode. This will be discussed later.

Observations as to blistering, pH changes, and chlorine formation were made, as well as current and voltage measurements.

Experimental Details

Solvent cleaned cold rolled steel panels 5½ by 10 inches were painted with two coats of the various paints. On one side of the panel there was a ½ by 4 inch bare steel area. The panels were partially immersed in 3 percent sodium chloride solution so that approximately 60 sq. in. of painted panel was below the surface of the water. Thus the ratio of painted to unpainted area was about 30 to 1.

Two sources of electric current were used:

1) The steel panels were coupled through resistors with magnesium panels of similar size and shape.
2) The steel panels were coupled in parallel and in series with carbon rods; an external EMF was imposed so that the steel panel was the cathode.

Two ranges of protective current density were selected. These were based on the bare metal area exposed. In one case it was about 0.4 milliamp per 2 sq. in. (approximately 29 ma. per sq. ft.). This current density was estimated to be in the order of magnitude of the required protective current under the exposure conditions. The other group received 7.0 ma. per 2 sq. in. (approximately 500 ma. per sq. ft.).

In the steel-magnesium combination the anode is readily oxidizable and the anodic reaction involves the passage of magnesium into solution as magnesium ion. Chlorine is not found in solution under these conditions.

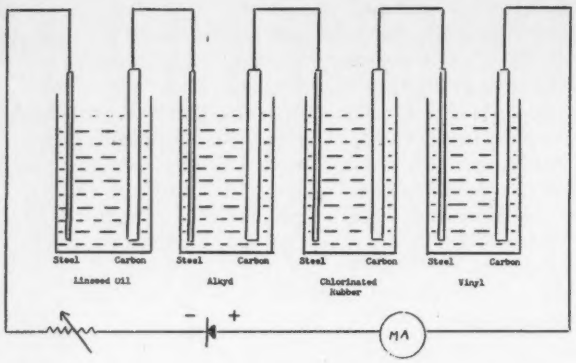


Figure 1—Painted steel—carbon cells in series. Electrolyte 3 percent commercial sodium chloride solution.

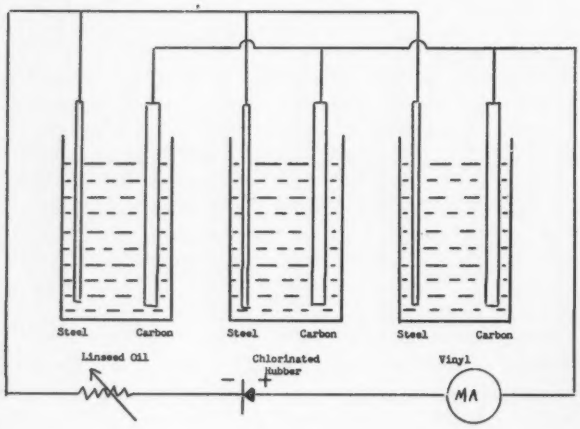


Figure 2—Painted steel-carbon cells in parallel. Electrolyte 3 percent commercial sodium chloride solution.

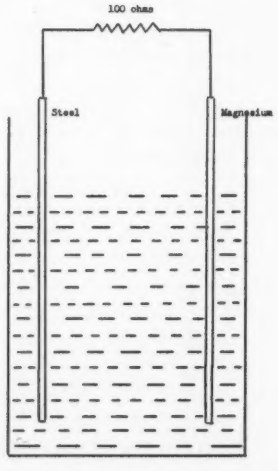


Figure 3—Painted steel panel coupled with magnesium (AM3S alloy) anode. Electrolyte 3 percent commercial sodium chloride solution.

With the steel panel-carbon anode combination two experimental arrangements were used.

1) The same current was maintained through each painted steel cathode throughout the test by connecting the group of cells in series.
2) The same applied voltage was maintained across each cell by connecting them in parallel. Under these conditions lowering of the cell resistance resulting from soaking of the paint film or from the extension of bare areas by lifting of the film would be accompanied by an increase of current through that particular cell.

The following photographs illustrate some of the effects described in the above part of this report. The panels were 5½ x 10 inches cold rolled steel, solvent cleaned, to remove grease and oil, prior to painting. The paint coatings were 2.5 to 3.0 mils thick. The diagonal strip which appears on all of the photos is the ½ x 4-inch bare steel window in the paint film. The descriptive matter photographed with each panel gives the nature of the vehicle used in the paint and the conditions to which the panel was exposed.

The first six pictures illustrate panels exposed to some type of cathodic protection. The last two pictures illustrate the effect of painted steel panels immersed in 5 percent sodium hydroxide. The paint

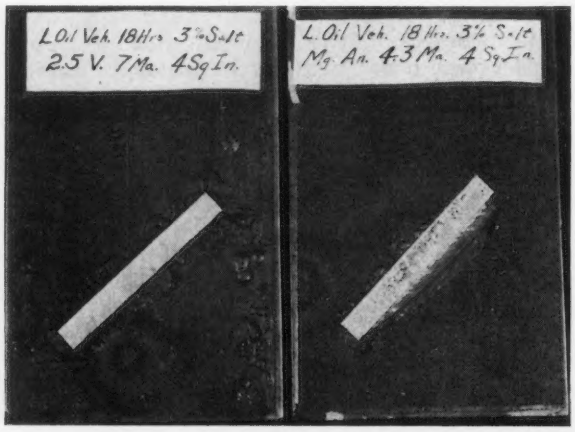


Figure 4

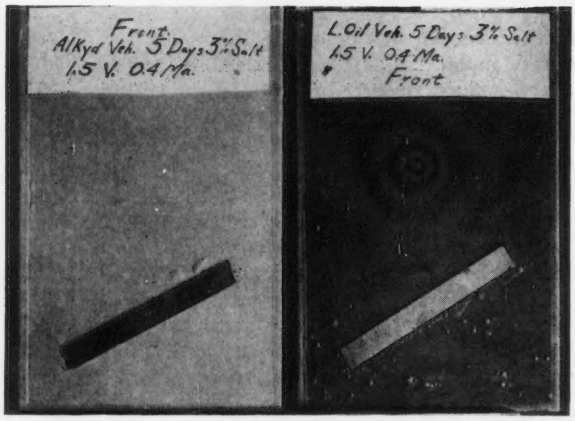


Figure 5

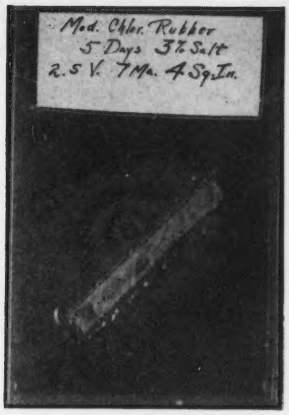


Figure 6

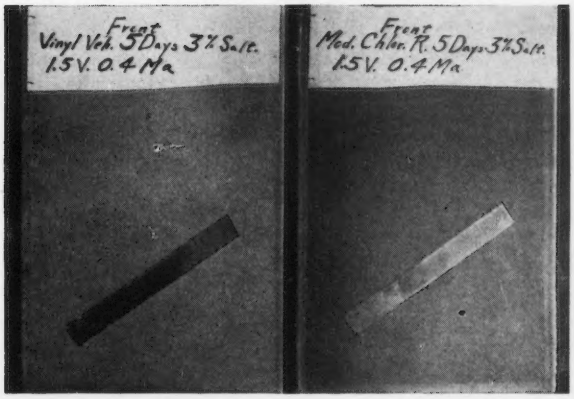


Figure 7

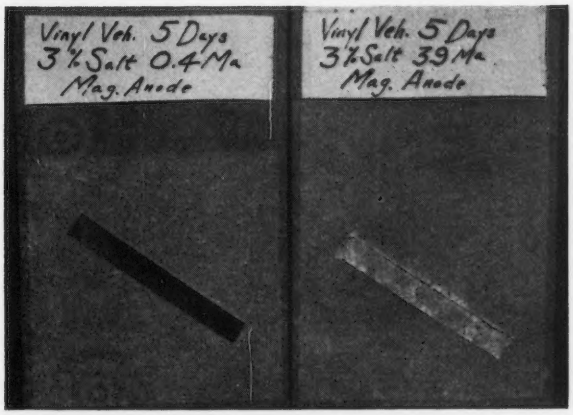


Figure 8

TABLE I

Carbon anodes with steel panels in 3% salt solution 0.4 milliamperes per 2 sq. in. bare steel—Series Circuit

Type Paint on Steel Panel	Linseed Oil	Alkyd Resin	Chlorinated Rubber	Vinyl Resin
Original voltage across cell	1.53	1.63	1.53	1.68
Voltage after 5 days	1.60	2.10	2.25	2.20
Original pH of salt solution	6.0	6.0	6.0	6.0
pH after 5 days	4.6	5.9	6.4	6.7
KI starch test for chlorine	Negative	Negative	Positive	Positive
Panel blistering 3 days	Condiserable	None	None	None
Panel blistering 5 days	Bad	Considerable	Slight	Considerable
Rust at Bare window after 5 days	Yes	No	No	No

The increase in voltage after 5 days may be due to polarization effects or film formation at the bare cathode area.

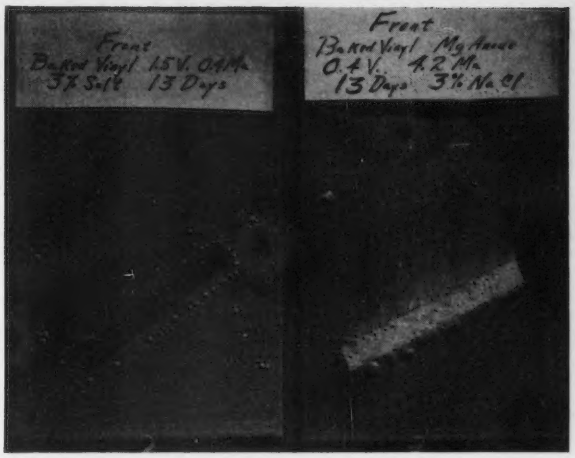


Figure 9

Figure 10

with the linseed oil vehicle (L.Oil Veh.) was entirely removed in 25 minutes. The alkyd vehicle paint was badly damaged in two hours. The chlorinated rubber and vinyl resin paints required a much longer time before the effects of caustic were apparent.

Discussion

In this work we did not evaluate the electro-osmotic properties of these paints. This property undoubtedly has a bearing on the performance of paints

TABLE II

Carbon anodes with steel panels in 3% salt solution 7.0 milliamperes per 2 sq. in. bare steel—Parallel Circuit

Type Paint on Steel Panel	Linseed Oil	Chlorinated Rubber	Vinyl Resin
Voltage across cell	2.5	2.5	2.5
Original pH of salt solution	6.0	6.0	6.0
pH after 18 hours	6.8	7.4	7.3
pH after 4 days	....	7.8	7.8
Blistering after 18 hours	Bad	None	None
Chlorine odor after 4 days	None detected	Strong	Strong

TABLE III

Type Paint on Steel Panel	Linseed Oil	Chlorinated Rubber	Vinyl Resin
IR millivolts (Initially)	435	380	420
IR millivolts (3 days)	....	330	382
Milliamps (Initially)	4.35	3.80	4.20
Milliamps (3 days)	....	3.30	3.82
Original pH	6.0	6.0	6.0
pH after 3 days	....	10.3	10.3
KI starch test for chlorine	....	Negative	Negative

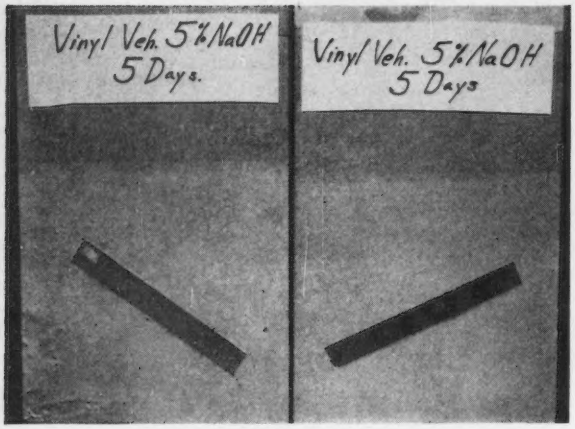


Figure 11

applied to cathodically protected steel. It is apparent also that current density is an important factor. Accelerated and out-of-door paint exposure tests have taught us that the method of cleaning the steel panel and its freedom from contaminants (oil, grease, rust, etc.), prior to application of paint, have a very considerable influence on paint performance. There is every reason to believe that those factors also affect performance of cathodically protected and painted steel surfaces. It may be debatable whether or not 5 percent aqueous sodium hydroxide is the proper concentration. Temperature is also a factor. Our tests were conducted at 70-75° F.

Conclusions

One of the important properties of paint films we did evaluate was alkali resistance. From these data and the photographs in this report it is obvious that there is a correlation between alkali resistance and cathodic protection performance.

Comment by Walter Beck, Lehigh University, Bethlehem, Pa.:

The experimental results secured by Dr. Eickhoff make evident that in many cases a considerable increase of pH in the electrolytic solution occurs. It is known that an alkaline reaction can exert an unfavorable influence on the durability of many paint combinations. As the photos show, blisters are formed on the paint film. The pH was measured in the bulk of the solution but it can be expected that the reaction immediately on the surface of the cathode and below the film will be still more alkaline. The blisters probably are filled with electrolyte and pH measurements in this solution might give valuable information.

Such measurements could be made by applying special electrodes such as are used in microbiology.

●

Halides As Acid Pickling Inhibitors by Karl F. Hager and Morris Rosenthal. *Corrosion*, **6**, No. 10, 344-346 (1950) Oct.

By R. B. Mears and J. M. Bialosky, Research Laboratory, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.:

We were interested in Hager and Rosenthal's paper which indicates that halides are effective inhibitors of the corrosion of steel in sulfuric acid. We note that their work was confined to stagnant solutions in covered beakers. Presumably under these conditions, a few minutes after the exposures were started the oxygen content in the solutions would fall to a very low value. It seemed important to determine if halides would serve as inhibitors in well-aerated sulfuric acid solutions. Therefore, we conducted an experiment to determine the corrosion rate of mild steel (SAE 1018) exposed to aerated 1 N H_2SO_4 at 30 C. The specimens were mounted on a circular path apparatus similar to that described by Fraser et al.[1]; so that they were in continuous motion during the exposure period. In addition, air was bubbled through the seven liters of sulfuric acid solution at a rate of five liters per minute.

The exposure was continued for 22 hours. Three similar steel specimens (1.75-inch diameter × 0.125-inch thick) were exposed under each condition in order to determine the average corrosion rate. In uninhibited 1 N H_2SO_4 the average corrosion rate for the 22-hour period was 574 mg/cm²/hr while in a 1 N H_2SO_4 solution inhibited with 0.1 per cent potassium iodide the average corrosion rate was 323. The efficiency of the potassium iodide under these conditions was thus about 44 percent. Under unaerated, stagnant conditions in solutions of similar sulfuric acid and sodium iodide concentrations, Hager and Rosenthal found sodium iodide was about 85 per cent effective as an inhibitor. Evidently the aeration and agitation has reduced the effectiveness of the iodide.

Hager and Rosenthal indicate that the halides function as inhibitors by increasing the polarization of the local anodes on the steel. This would mean that the apparent single potential of steel should move in a cathodic or noble direction if a halide were added to the sulfuric acid in which the steel was immersed. We found, however, that the apparent single potentials of steel specimens in sulfuric acid containing potassium iodide were more anodic (about —0.505 volts against a saturated calomel half cell) than were the potentials of similar specimens exposed to uninhibited sulfuric acid (about —0.485 volts). Thus, it appears that the iodide probably functions as an inhibitor, in part at least, by increasing cathode polarization. Aeration and agitation would both be expected to reduce cathodic polarization and this may explain why the effectiveness of the iodide as an inhibitor was lower in our aerated and agitated conditions than was the case with Hager and Rosenthal's stagnant conditions.

Authors' Reply:

We agreed that the addition of iodine increases the cathodic polarization, therefore, aeration and agitation reduce the inhibiting properties of iodine due to the decreasing of the cathodic polarization.

In order to combat this susceptibility, small concentrations of additives ranging from ethanol to water-soluble cutting oils are being tested in conjunction with lowered amounts of iodides so as to stabilize the increased cathodic polarization due to the iodides.

The credit for the inhibiting properties of the halides, however, cannot be given to increases in cathodic polarization alone, but may be due in part to the introduction of high transfer resistance between the solution and the metal surface. Further investigation of the reaction mechanism would be of great interest to electrochemists.

1. O. B. J. Fraser, D. E. Ackerman and J. W. Sand. *Ind. Eng. Chem.* **19**, 332 (1927).

Topic of the Month

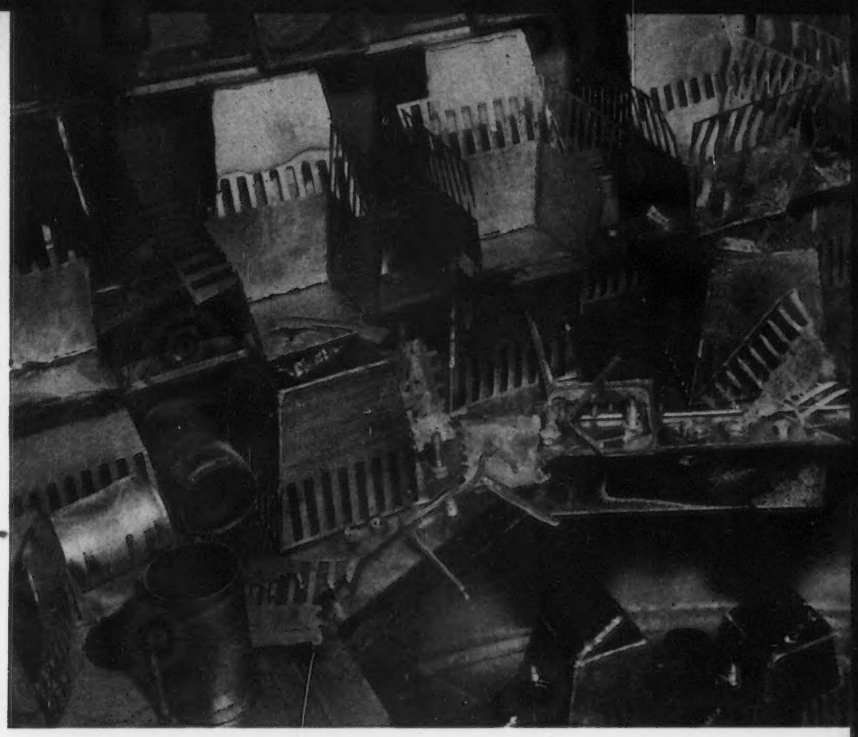
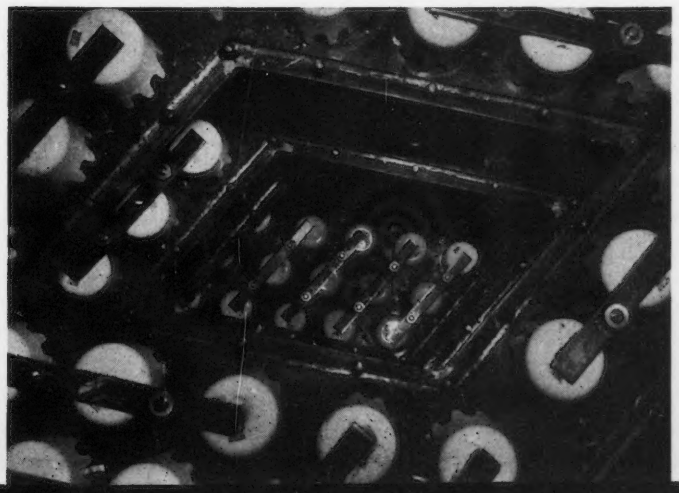


Figure 1

Figure 2

Figure 3



Corrosion of Bubble Caps In a Chemical Plant

By CLYDE W. DAY, R. C. SCHUELER* and E. V. KUNKEL**

SEVERE CORROSION was encountered in bubble cap installations in an acetic acid unit where they were exposed to various concentrations of acetic acid at temperatures in the range 200-300° F. The bubble caps used were fabricated from 14 and 16 gage, Type 316 and 317 stainless steel, and consisted of several types:

1. Square base truncated pyramid, heat treated.
2. Square base truncated pyramid, non-heat treated.
3. Round, drawn, heat treated.

Figure 1 is typical of the extent of corrosion encountered after from one to two years' service.

This was one of many corrosion problems in the acid unit, but, since efficiency of the unit was involved, the problem was thoroughly investigated in our active program for mitigation of corrosion. Many materials were tested over a period of time but no metals were found which were especially desirable for installation as bubble caps.

Available ceramic materials were investigated and a design was prepared for manufacture of several test caps and risers. These caps were installed in a service at a temperature of 200-250° F. and were unsatisfactory due to porosity and lack of sufficient strength to survive the rough handling received during installation and repair turnarounds. Figure 2 shows the typical condition of these caps and risers after approximately six months of service.

An improved ceramic was developed some time later and a complete installation of ceramic caps was made (Figure 3) in a tower operating in the range of 245-275° F. The intertray manways of this tower have been removed four times during the 1½ years of service and, although no special precautions were taken, only four caps have been broken. The media in the tower was clean, however, and no manual cleaning has been required.

* Corrosion Engineering Section, Celanese Corporation of America, Chemical Division, Bishop, Texas.

NACE News

Inhibitors and Use Of Magnesium Are Baltimore Topics

"Chemical Inhibition of Corrosion," by George E. Best, Technical Service Engineer for The Mutual Chemical Company of America and vice-chairman of Baltimore Section NACE and "Combating Corrosion with the Metal from the Sea," by G. E. Mullin, District Chemist for Dowell Incorporated where the scheduled technical topics for the February 7 meeting of Philadelphia Section. The dinner meeting at the Poor Richard Club, Philadelphia, was scheduled to begin at 6:30 p.m.

Bacterial Corrosion

R. L. Starkey, professor of Microbiology of Rutgers University, New Brunswick, N. J. is the scheduled speaker for the February 7 meeting of Metropolitan Section at Building Trades Association Building, 2 Park Ave., New York. Dinner will be served at 6:30 p.m. and the formal meeting will follow.

V. N. Jenkins Attends Chicago Section's Christmas Meeting

Vance N. Jenkins, NACE president and director of research for Union Oil Company of California was principal speaker at the December 12 Christmas Party meeting of Chicago Section. The dinner meeting at Chicago Engineers Club also was featured by the showing of some colored slides of an Australian one-coat protective coating for general corrosive conditions which is reported to have provided cathodic protection to metal surfaces for periods up to 10 years. G. E. Seidel, of Amercoat Corporation provided commentary on the slides.

Amercoat Corporation was host to the section for the social hour. H. L. O'Brien, program chairman, presided at the meeting.

Protective Coatings

I. L. Toler of Humble Oil & Refining Co., Houston, Texas, was the scheduled speaker on the subject "Paints and Protective Coatings" before the New Orleans-Baton Rouge Section dinner meeting at Pallud's Restaurant, Baton Rouge. Attendance by 20 members and 10 guests was forecast.

Petition Filed For Detroit Section

NACE CALENDAR

Feb.
16 Houston Section. Joint meeting with Houston Chapter of American Institute of Chemical Engineers. Principal speaker, F. L. Whitney, Jr., Monsanto Chemical Co., St. Louis, Mo. Visit to Sheffield Steel Corp. plant also scheduled.
20 Chicago Section. "Corrosion Control by Water Conditioning," by Nat A. Bailey, Wright Chemical Co. Chairman, J. Pat Casey, Crane Company.
20 Cleveland Section.
28 Corpus Christi Section.

Mar.
1 Pittsburgh Section. "Corrosion Promoted by Organic Coatings, G. W. Seagren, Stoner-Mudge Protective Coatings Fellowship, Mellon Institute.

Two Speakers Cover Refinery Corrosion At Shreveport Meeting

A. W. Trusty addressed members of Shreveport Section at a dinner meeting November 9 at the Caddo Hotel, Shreveport, La. on refinery corrosion, showing by charts the effects of temperature and hydrogen sulfide and giving methods of combating them. Dave Wilson then, illustrating his talk with a schematic drawing of a refinery, pointed out the most likely places for corrosion to occur and suggested different metals for combating corrosion at these points. Brief discussions followed presentation of both talks. Both speakers were introduced by J. O. Griffin.

Vice-Chairman Tom Holcombe named Pat Miller and Ed Sullivan to prepare for a Christmas party to be held during December. A general pipe line discussion was scheduled to be a part of the program also.

Mr. Holcombe expressed regret only 21 members were present at the meeting to hear the two excellent talks.

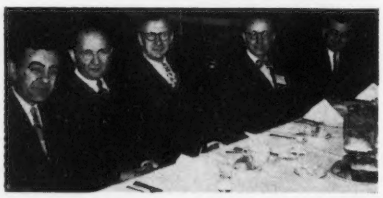
Corrosion News Deadline:
10th of Month *PRECEDING* Date of Issue

A petition signed by twelve members of NACE has been filed with A. B. Campbell, executive secretary of the association for the formation of a section in Detroit, Mich. Jack N. LoPrete, acting secretary, of Spray-Coat Engineers, Detroit, said the twelve signees were present at a charter meeting and that a meeting has been scheduled for January 18.

St. Louis Members Hold Panel Session On Corrosion Problems

Small informal groups continued discussions about various corrosion problems discussed by a panel at the December 18 meeting of Greater St. Louis Section. This indicated the success of this type of meeting because the formal meeting was continued for about two hours after the panel discussed technical questions presented and prepared before the meeting.

The panel, moderated by Dean L. E. Stout of Washington School of Engineering, consisting of C. M. Blair, W. H. Keller, L. D. McCoy and R. D. Rodrian discussed prepared questions pertaining to corrosion ranging from selling management on the corrosion engineer's program to materials of construction for a bubble cap fractionating column handling separation of ethyl chloracetate, ethanol, monochloracetic acid and water. Technical aspects of each of 16 questions were covered, and comments by the panel emphasized the importance of proper fabrication techniques as well as material selection. Many corrosion problems, they brought out, develop rather from construction methods employed than from inappropriate materials.



PANEL AT ST. LOUIS: R. H. Rodrian, W. H. Keller, L. E. Stout, C. M. Blair and L. D. McCoy.

(In December, 1950, on Page 3 of the NACE News section the report of the St. Louis Section meeting included the name of the principal speaker incorrectly spelled. The name of the speaker was Glen A. Fritzlen.)

Aluminum Pipe Test Shows Poor Service With Sour Crudes

Aluminum pipe is unsatisfactory for sour crude service, experience of Interstate Oil Pipe Line Company indicates, it was reported by E. C. Mishou to members of Shreveport Section NACE at a December 14 meeting at Caddo Hotel, Shreveport. Mr. Mishou's talk was on the joint project between Interstate and the Carter Research Laboratory in which aluminum pipe was laid in an effort to find a substitute for steel pipe which would be resistant to external and internal corrosion.

The pipe consists of a total of 5½ miles of 6-inch 63S-T6 alloy in sour crude service in the Magnolia, Arkansas district and one mile of 4-inch of which one-half mile is in sour crude service in Arkansas and one-half mile in sweet crude service in South Louisiana marshland near the Gulf of Mexico. Taking into account all costs the overall outlay for the aluminum pipe was about 8 percent higher than that for steel pipe.

Flanged sections in the pipe laid for sour crude service provide a means of inspecting the line for internal corrosion. Internal pits 1/16-inch deep were observed after seven months' service and a leak appeared after 27 months' service in the 4-inch aluminum pipe used as a suction line. In that part of the pipe used as a discharge line, where the pressure is between 400 and 500 psi, no leaks have appeared but severe internal corrosion has been observed.

Aluminum Pipe Unsuccessful

From these observations it was decided that aluminum pipe does not prove successful in sour crude service. Steel pipe has held up for as long as four to seven years under the same conditions.

Mr. Mishou said no external corrosion had been noticed on any of the aluminum pipe in the Magnolia district or that installed in the Louisian marsh.

Following Mr. Mishou's talk a 6-inch section of aluminum pipe from that installed in sour crude service was passed along for examination, together with an aluminum stud bolt and a piece showing a weld test.

Matagorda Test Under Way

Mr. Wanderer of the Aluminum Company of America, the next speaker, told of 3500 feet of 4-inch aluminum pipe laid in salt water in Matagorda Bay at Port Lavaca for use as a gas line. This is a solid welded line weighted with concrete. Aluminum pipe floats down to one-inch size. Half the line was coated and wrapped and the other half laid bare. The sections are insulated from one another.

Because the line has been laid a short time only, Mr. Wanderer said it was too soon to tell how the pipe would react. He pointed out that the corrosion curve for aluminum goes up slightly for about five years then levels off.

Discussion Follows

Many interesting questions were answered by the speaker during the discussion. He said aluminum pipe made by Alcoa ranged from ⅛ to 12 inches in size and that the safe gas working pressure of 12-inch line would be about 650 psi. Mr. Wanderer said a test section of aluminum in the hull of a ship has held up for 14 years.

Vice-Chairman Tom Holcombe presided. There were 37 members and guests present. Cocktails were served preceding dinner through courtesy of Aluminum Company of America, American Packing and Gasket Company, Graybar Electric Company and Holcombe and Stearns.

Lubrication Engineers

The American Society of Lubrication Engineers will hold its seventh annual convention and fifth annual lubrication show at Cleveland, Ohio, Hotel Statler, April 7-,9 1952.

Engineers' Council Report is Issued

The Eighteenth Annual Report of the Engineers' Council for Professional Development for year ending September 30, 1950, has been issued. Accomplishments during the past year recorded by the council include: A report on the "First Five Years of Professional Development," revised rules of procedure, adoption of canons of ethics by all eight participating societies and others.

■

Copies of most back issues of CORROSION are available for sale: To NACE members, 50c per copy; to non-members, 75c.

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★ Cold Applied Tar Base Coatings—Series 100
★ Alkyd Base Coatings—Series 200
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Attend the N.A.C.E. Convention in New York City, March 13th to 16th

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Panel at Houston Discusses Internal Pipe Line Corrosion

"The Internal Corrosion of Pipelines" a panel discussion, was the featured technical item on the January 9 Houston Section dinner meeting. R. A. Brannon, Humble Pipe Line Co., was panel moderator; panel members were Walter Rogers, Gulf Oil Corp., and A. W. McAnneny, Fish Pipeline Construction Co. Mr. McAnneny told of work done in West Texas where sour crude has caused severe corrosion. Ammonia has been used with some success, but the problem of controlled injection has presented some difficulty.

Mr. Rogers told of experience of his and other companies operating in sour crude areas, especially with protective coatings and resistant materials. Cement-lined pipe has been used with some success, he said, but the difficulty of protecting joints has in some cases limited its efficacy. Loss of flow volume as well as increased weight also are deficiencies. Asbestos-cement pipe also has proved effective in combating corrosion where pressures are low, as in field gathering lines.

Developments in internal cleaning and coating of pipe lines in place recently used in West Texas with encouraging success also were discussed by Mr. Rogers. Further improvement are needed and apparently are being given attention, he said.

L. A. Baldwin, Johns-Manville Sales Corp., New York, a director of NACE gave a brief but informative review of the work of the Regional Management Committee of which he is chairman.

A joint meeting of Houston Section and Houston Chapter of the American Chemical Engineers is planned for February 16. Mr. Frank L. Whitney, Jr., Monsanto Chemical Co., St. Louis, Mo., chairman of St. Louis Section, will be principal speaker. The program also includes a tour of the Sheffield Steel Corp. plant on the Houston Ship Channel.

San Francisco Section Hears Wachter on Corrosion Inhibitors

"Corrosion Inhibitors for Aqueous Systems," was the topic of an address by A. Wachter of Shell Development Company before a November 15 meeting of San Francisco Bay Area Section NACE at El Jardin Restaurant, San Francisco. There were present 36 members and guests.

Dr. Wachter covered in detail the field of aqueous inhibitors, and the lively discussion following was indicative of the considerable interest aroused. Covered by Dr. Wachter were: theory of corrosion inhibitors, guides for selection, uses for inhibitors and a detailed survey of available inhibitors, their advantages and shortcomings.

Actual comparative corrosion rates for many types of inhibitors under service conditions were given. These data illustrated the importance of such factors as pH, temperature, oxygen concentration and maintaining the concentration of the inhibitor. The speaker also stressed the need for more fundamental research and intelligent application of inhibitors in the field.

New officers for 1951 elected by the section were: Robert J. King, chairman, Standard Oil of California, Materials Laboratory, Richmond Refinery, Richmond, Cal.; David Hendrickson, vice-chairman; East Bay Municipal District, Oakland, Cal. and Charles E. Haney, Secretary-treasurer, Electric Steel Foundry, San Francisco, Cal.

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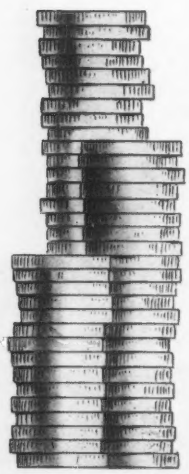

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Examples of Repairs and Fabrication to Cut Corrosion Given

Following is the summary of a talk given November 15, 1950, by M. A. Scheil, Director of Metallurgical Research, A. O. Smith Corp., Milwaukee, Wis., before a joint meeting of the National Association of Corrosion Engineers' Western New York Section and North East Region:

Some welded ½-inch and ⅜-inch thick Type 302 stainless steel retorts containing 0.16 percent C were cited as an example of early fabrication (1930) when little was known about the cause and cure for intergranular corrosion. Failure occurred by cracking and intergranular attack in the heat affected zone of girth welds after 17 years of satisfactory operation by reason of a process change which introduced corrosion factors harmful to the sensitized structure of the Type 302. Cracking of an intergranular nature was accelerated by local tension stresses.

The retorts were placed in first-class condition by careful Zyglo inspection to detect the zones of intergranular attack removing the metal affected by intergranular attack, rewelding the seams and building up the walls to original thickness and finally heating to 1950° F and air cooling. The repair procedure was carefully checked with laboratory corrosion tests and satisfied the requirements for 18-8 free from harmful carbide precipitation.

It was mentioned that Type 430 retort which had been annealed at 1450° F. after original fabrication did not suffer any corrosion attack under the same service conditions. The straight chromium ferritic stainless steels are usually not subject to intergranular attack in service.

New Alloys Unaffected

Mr. Scheil pointed out that present day 18-8 with either extra low carbon or with appropriate stabilizers for carbon would not be subject to harmful carbide precipitation upon welding. The case was of interest because of the long successful use of the retorts with bad carbide precipitation present until a slight modification of process introduced factors necessary for intergranular attack.

An example of the failure by cracking of several hundred flat screen plates made of 18-8 Type 304 for classifying sulfite pulp fiber in a dilute white water suspension with pH 4.5 to 5.5 was discussed. The problem was to decide whether failure was due to stress corrosion or corrosion fatigue. It was pointed out that in forming the flat screens of 1/16-inch thickness the edges were bent at 90° and caused hardness to increase from 121 to 257 Vickers. The nature of the cracks were transgranular and branching suggesting stress corrosion.

A complete screen plate assembly with milled slots .008 inch wide was annealed by heating to 1950° F. This section was placed in the vibrating screen and run successfully for several months. This evidence would confirm the original analysis of stress corrosion failure.

The speaker stated that of conditions which lead to transgranular stress corrosion, intercrystalline stresses seem to have a greater tendency to cause cracking than an imposed stress on an annealed material.

Type 347 Stress Cracking

Laboratory work with stressed beam specimens of Type 347 stainless steel, annealed at 1600° F and tested in 42 percent boiling magnesium chloride at 309° F were shown to stress crack at stress levels above and below the yield strength. The speaker mentioned that the threshold stress to cause transgranular cracking was in the neighborhood of 10,000 psi tension.

Autoclave Corrosion Discussed

An example of stress corrosion cracking in a 1½-inch thick autoclave of Type 347 stainless steel was discucssed. The autoclave was handling 70 percent caustic with organic salts at 525° F and 255 psi. To prove that failure was due to stress corrosion small stressed specimens of the same material and heat treatment were exposed to the same process carried out in a small laboratory autoclave. Specimens were stressed at 40,000, 30,000, 20,000 and 14,500 psi. Those stressed above 14,500 psi failed by stress cracking and the specimen stressed at 20,000 psi cracked in a length of time similar to the production autoclave. These tests indicated that stresses in operation were of the order of 20,000 psi tension on the

(Continued on Page 6)

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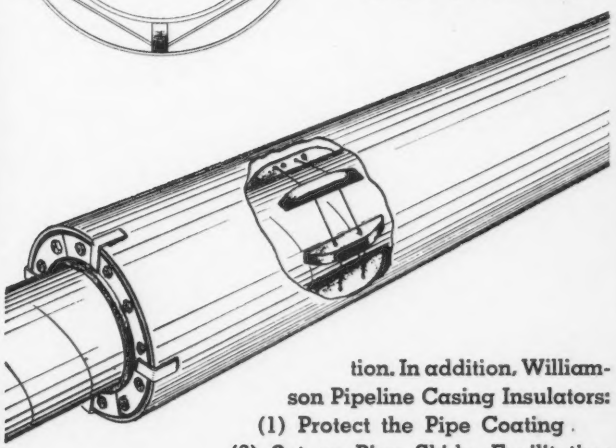

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Examples of Repairs—

(Continued from Page 5)

service surface which were believed to be high due to the oil flame used to heat the autoclave.

Coke Drum Growth

The speaker discussed the growth of coke drums fabricated of carbon steel which operate at about 850-900° F and are force cooled with steam and cold water. The growth is due to chilling of the inside surface of the vessel while the outside surface is hot under its insulation. Under these conditions the shell sections grow continuously by reason of elongation due to thermal temperature gradients.

An example of a particular vessel subject to these conditions was discussed where it was found that from temperature-impact tests the transition temperature of the steel was about 135° F. Stress relieving at temperatures above 1150° F improved the notch toughness of the steel and improvement was believed due to the solution of an aging constituent in the material. The precipitate at the ferrite grain boundaries believed responsible for charpy keyhole notch values of 5 ft. lb. had no deleterious effect on the tension properties of the steel. Periodic hydro testing of the vessel with this material after about ten years of service resulted in some girth cracks appearing in the shell plates when testing was carried out at about 60° F. The probable cause of these craccks was attributed to a change in notch toughness at room temperature brought about by service conditions.

Alloys Testing Described

A standard test for alloys in 85 percent boiling ortho-phosphoric acid was described and the importance of small amounts of copper in Type 316 stainless steel was shown to considerably improve the corrosion resistance. Copper to the extent of ¼ to ½ percent in 25 percent Cr—20 percent Ni and 3 Mo weld metal is very beneficial to the corrosion resistance.

Copper ions in the phosphoric acid testing solution were shown to produce a marked effect on the corrosion rate. For instance, Type 304 low carbon gave 16.4 ipy in 85 percent phosphoric acid boiling with no copper ions. With the addition of 0.1 percent copper to the acid the same stainless had a rate of 0.045 ipy. Type 316, with low carbon .03 percent max and low copper content had a rate of 2.64 ipy in phosphoric acid with no copper added. After an addition of .001 percent copper to the test solution the rate became 0.124 ipy.

The laboratory test was to provide a gage with which to measure whether a heat of a particular material is superior or inferior in its corrosion resisting properties or if fabrication procedures alter the corrosion resistance.

Mr. Scheil said his laboratory has found this test most useful. A paper describing the test was presented at the ASME Petroleum Mechanical Engineering Conference, Fall Meeting, New Orleans, Louisiana, September 25-27, 1950, and will be published.

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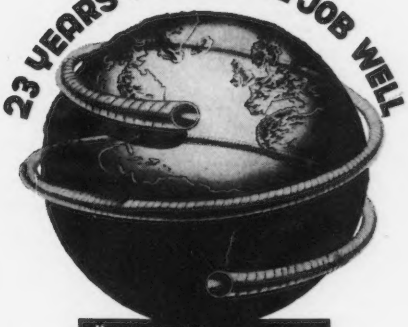

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Characteristics of Oil Additive Agents Are Enumerated

(Presented Before Western New York Meeting, Buffalo, New York, November 15, 1950.)

By A. A. O'Kelly, Alox Corp., Niagara Falls, N. Y.

The title assigned for preparation of this paper has been taken literally and broadly to cover the whole gamut of oil additive applications. The author's personal background centers largely around the use of addition agents in motor oils while that of the Alox Corporation embraces a broader field particularly, for the moment, centering in rust preventives, corrosion inhibitors and more generally fuel and lubricant additives. This paper then will be an attempt to blend these two backgrounds into an informative discussion of the subject of oil addition agents.

The present-day annual gross dollar volume of the oil additive business has been variously estimated in the neighborhood of $50,000,000. This has not come about overnight but has been a process of slow growth as new requirements in the lubricant, fuel and corrosion preventive fields have been brought about. While it is not novel, the thought will, nevertheless, bear repeating that nature's foresight and chemical magic was not sufficient to foretell all the requirements man would make on its product so that there are certain directions in which man's ingenuity has been called upon to enhance natural products for more effective job performance.

In a general manner, I want to recall the several applications of addition agents to motor and preservative oils, then to return to some of these for more specific comments.

Additives Are Enumerated

Probably at the head of the list in everyday parlance stand detergents, antioxidants, viscosity index improvers, and rust preventives. It is not proper to employ the term corrosion inhibitor here because in additive terminology as applied to motor oils, corrosion is related more specifically to the etching effects of acids upon bearing alloys as determined by bearing weight loss in engine operation. To a lesser extent, pour depressants, oiliness agents, etc., are important in enhancing the performance characteristics of engine oils.

In turbine-circulating oils two distinctly different but equally important additive requirements are found. These are the rust prevention and anti-oxidant properties. The former is generally met in a surface active agent capable, we believe, of chemically bonding—in monolayer—with metals and simultaneously presenting to a surrounding oil-water body an oil-loving chain which immediately implies a hydrophohic chain. In this manner, physically, at least to a certain extent, water is withheld from the metal surface and rusting is inhibited. The antioxidant, on the other hand, is an organic, oil-soluble, compound such as e.g., phenyl alphanaphthylamine, ditertiarybutyl paracresol, etc. No discussion of a mechanism for action of these products in preventing turbine oil deterioration through oxidation is attempted here.

Gear lubricants represent one of the most extreme requirements known in addition agent performance. The term extreme pressure lubricant additives is actually more appropriate in describing the severity of these requirements. Here chemical bonding undoubtedly is an important factor because under pressures of many thousands of pounds per square inch, some product must be used which will not squeeze out but which will stay on the gear tooth under these pressures and hold enough oil "in place" for lubrication. Since chlorine and sulfur compounds are effective in such applications, there is also good evidence for the formation of a thin film of iron chloride and iron sulfide on the gear teeth, resulting in an inorganic lubricant being formed "in situ." In such lubricants rust and corrosion prevention are important factors and there is considerable evidence to indicate that these factors as well as that of an added lubricity factor are met by acid-esters which, performance-wise, now have an enviable position, in the extreme pressure additive field.

Cutting Oils Are Related

Mineral cutting oils, in a large sense, are closely related to extreme pressure additives. Here again pressures are high, local high temperatures are encountered, and tool life prolongation as well as prevention of metal tearing are extremely important. The clean metal surfaces developed should not rust and so rust preventive compounds are important in cutting oil formulations also. Similarly to gear lubricants sulfur and chlorine compounds have been used quite generally in these products but more recently certain ester-type compounds sometimes referred to as lubricity agents, have, as previously referred to under extreme pressure additives, been found to prolong tool life and provide high tapping efficiencies in mineral cutting oil evaluation. These go far toward eliminating the odorous sulfur compounds so long associated with cutting oils.

Anti-Oxidants and Detergents

Let us return now to a consideration of certain aspects of motor oil antioxidants and detergents. It is fairly safe to say that no *true* antioxidant exists for motor oils at conventional operation temperatures. Presumably, if one could operate on a purely hydrocarbon fuel, such as unleaded isooctane, e.g., and employ a *true* antioxidant in the oil, sludge would be virtually unknown and lubricating oil quality would be maintained at a high level. Since neither of the above requirements is possible in practice, it may be interesting to look at the practical side of maintaining lube oil quality in engines.

This is a particularly acute matter when high sulfur fuels are burned in which case the development of sludge in the oil varies directly with the sulfur content of the gasoline.

The relationship between sulfur content of gasoline and sludge formation in the crankcase oil indicates clearly the production of products of combustion in the combustion chamber which blow by

(Continued on Page 9)

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Characteristics of—

(Continued from Page 8)

the piston under compression and react with the oil to produce sludge. The piston, in between, and the retaining cylinder wall become a chemical reaction zone, due to oil and "blowby" vapor contact on them while hot, to result in lacquer, varnish, and carbon deposition in the ring grooves and on the skirt.

There is ample unpublished evidence to indicate that the blowby gases which cause these troubles are sulfur dioxide and trioxide formed in the fuel combustion. So-called motor oil detergents, now generally metalo-organic compounds such as metal waxbenzenesulfonates can minimize the effect of blowby SO_2 and SO_3. Further unpublished data show that the effectiveness of these products is proportional to their basicity. To illustrate, a basic barium waxbenzenesulfonate is considerably more effective than a neutral barium waxbenzenesulfonate.

High Dosages Are Used

The recent ambition of many oil companies to qualify Supplement I and II motor oils where high sulfur fuels are the important factor, has lead to metallic detergent additive dosages as high as 20% by weight. This soon leads the oil refiner to wonder if he should be in the in the oil or chemical additive business. Such high dosages of metal-bearing additives leads inevitably to various engine deposits and obviously is not a long-range and final solution to the problem of maintaining bright pistons and otherwise clean engines operating on high-sulfur fuels.

In passing it may be interesting to cite an experiment from other unpublished information to prove the need for an alkaline product as a motor oil detergent in high sulfur fuel operation. A single cylinder engine was operated on a fuel containing 2 percent sulfur and a lubricating oil to which had been added 10 percent of a 10 percent solution of caustic soda in water. The piston was bright, there were virtually no deposits, and sodium sulfate was found in the crankcase after the run. Furthermore, upon settling and emulsion separation, the oil was also bright. The evidence is therefore great that control of SO_2 and SO_3 in contact with the crankcase oil is as important as, if not more important than, control by oxidation inhibition.

One further important factor in motor oil quality is control of rusting in the engine under intermittent operating conditions when the system is intermittently hot and cold, resulting in considerable crankcase breathing and resultant water accumulation in the oil sump.

While there are many other applications of additives in oils such as in penetrating oils, metal drawing compounds, roll oils, soluble cutting oils, break-in oils, ceramic oils, marine oils, etc., this discussion will be closed with a brief

(Continued on Page 10)

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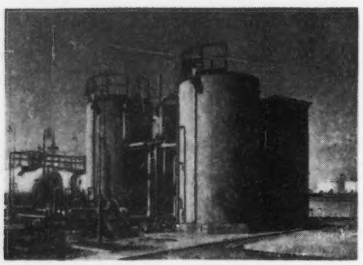
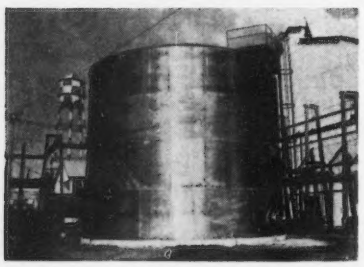
3 Cases where a CORROSION problem was solved by using alloy metals

1. **STAINLESS STEEL** — The two acid-feed surge tanks shown at the left are located at the Phillips Chemical Company plant at Etter, Texas. They store the nitric acid that is used in the manufacture of ammonium nitrate. The tanks are built of lightweight type 347 solid stainless steel plates with a carbon steel framing.



2. **NICKEL**—The tanks shown at the left are made of nickel-clad steel plates. They are used for intermediate storage of glycerine by the Shell Chemical Corp., at Houston, Texas. Nickel was selected to minimize contamination of the glycerine. The tanks are insulated with magnesia to maintain the temperature of the glycerine during storage.



3. **ALUMINUM** — This tank is used to store the ammonium nitrate solution being produced at the Spencer Chemical Company's petrochemical plant in Military, Kansas. The shell and bottom are made of aluminum to prevent metallic contamination of the acidic salt solution during storage. The umbrella roof of the tank is made of carbon steel.

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Characteristics of–

(Continued from Page 9)

consideration of one of the most important fields of additive application which is that of preservative lubricants.

Oil Alone Not Enough

Time was when a film of mineral oil was thought to provide considerable rust protection before tests were set up to actually determine its effectiveness. Really, straight mineral oils provide very little protection of clean metal surfaces against even air-moisture contact or atmospheric corrosion. This failing is more evident in the instance of salt water and corrosive gases from industry, such as chlorine, hydrogen sulfide, etc. Certainly during the past several years the latter has become accented considerably in the overseas shipment of equipment in quantity by the armed forces.

A number of oil-soluble products have been developed for the protection of polished metal surfaces from ball bearings to Bofors guns. The uncertainty of atmospheric conditions under which metal parts and finished products will be stored or transported has made it almost imperative that additives employed in the oil preservative coatings have certain capabilities for protecting in the conventional salt spray test as well as in the humidity cabinet test and shed test designed to meet definite requirements.

It will perhaps suffice to cite only a few applications of preservative lubricants. Excessive rusting of engines and parts in humid storage during the last general war led to the development of this particular class of preservative oils which has been designed not only to limit moisture rusting but at the same time guard against acid vapor corrosion. In the direction of prevention of moisture rusting, the metal sulfonates, wool grease, and esters and soaps of various fatty acids and organic acids derived from oxidized hydrocarbons, are normally used as additives to oils. The organic phosphates and amines and amine salts, on the other hand, afford a mineral oil halogen acid corrosion resistance. As further applications of preservative lubricants, the interest of the farmer, the manufacturer and user of outboard motors and seagoing pleasure craft must be satisfied. These represent no small fields of usage of these products. A detailed discussion of this specialized class of oils is given by H. Sellei and E. Leiber in *Lubr. Engineering*, pages 16-23 and 42-45 for September, 1945. This will undoubtedly be a field of considerable product development in the next few years.

Missing Ingredient in Paint Remover Given

In the article "Improved Paint Remover Is Formulated by Dow" published on Page 13 of the December, 1950, issue of CORROSION, an ingredient in the formula was omitted. The material omitted was:

Methocel, 4000 cps, PRG . . 13 lb.

Several alert readers of CORROSION have pointed out the omission.

Fifteen Lecturers for Corrosion Course at Stevens Are Named

Fifteen lecturers have been named for the Corrosion Prevention Seminar to be held at Stevens Institute of Technology, Hoboken, N. J. beginning February 7. The seminar is sponsored by the National Association of Corrosion Engineers. The public is invited to attend the talks, which are part of a graduate level course on corrosion.

Meetings will be held weekly on Wednesday nights starting at 8 p.m.

Fees for the course have been set as follows:

Students regularly enrolled at the institute in the corrosion course will pay no fee in addition to their normal tuition.

Members of NACE, $20.

Non-members of NACE who apply for membership at the time or registration, $27.50, (of this amount $7.50 is for a year's dues of the association).

All others, $25.

Lecture dates, topics and speakers are listed below:

Feb. 7—Review of Corrosion Factors, T. P. May, The International Nickel Co., Inc., New York, N. Y.

Feb. 14—Design Features, R. H. Brown, Aluminum Company of America.

Feb. 21—Humidity Control, Paul H. Bachman, Davison Chemical Co., Baltimore, Md.

Feb. 28—Deaeration, J. D. Yoder, The Permutit Co., New York, N. Y.

Mar. 7—Inhibitors, G. E. Best, Mutual Chemical Co., Baltimore, Md.

Mar. 14—Light Metal and Alloys, E. D. Verink, Aluminum Co. of America.

Mar. 28—Copper and Its Alloys, C. L. Bulow, Bridgeport Brass Co., Bridgeport, Conn.

Apr. 4—Nickel and Its Alloys, W. Z. Friend, International Nickel Co.

Apr. 11—Iron and Stainless Alloys, F. L. LaQue, International Nickel Co.

Apr. 18—High Temperature Alloys, E. M. Skinner, International Nickel Co.

Apr. 25—Electrodeposited Metal Coatings, C. H. Sample, International Nickel Co.

May 2—Alloys of Lead, Zinc, etc., G. O. Hiers, National Lead Company, Brooklyn, N. Y.

May 9—Cathodic Protection, L. H. Sudrabin, Electro Rust-Proofing Corp., Belleville, N. J.

May 16—Paints and Organic Coatings, R. M. Burns, Bell Telephone Laboratories, Murray Hill, N. J.

May 23—Plastics, Rubber, Nonmetals, Kenneth Tator, Coraopolis, Pa.

Summer Corrosion Course at MIT Is Scheduled June 18-23

Lectures and demonstrations to cover a 5½-day period are being planned for a summer course in corrosion to be given June 18-23 at Massachusetts Institute of Technology, Cambridge, Mass. The course is designed primarily for those who want a refresher in fundamentals and provides as well an opportunity to learn latest developments in combating corrosion of industrial equipment.

H. H. Uhlig, professor in charge of

(Continued on Page 12)

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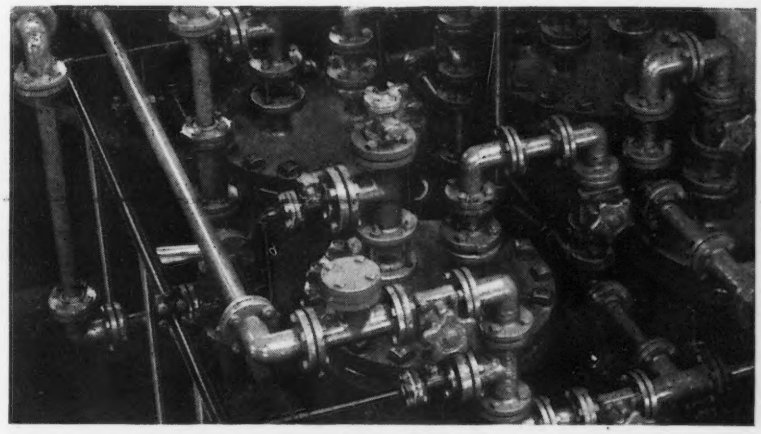

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Summer Corrosion–

(Continued from Page 11)

the MIT Corrosion Laboratory said subjects scheduled to be covered during the course were: 1) Fundamentals of corrosion reactions and control; 2) metals and alloys, metallurgical properties, guide to proper selection; 3) cathodic protection, theory and practice; 4) coatings — metallic, selection, behavior in corrosive environments; organic, selection, application and behavior; 5) treatment of enviroment; 6) design of equipment from a corrosion standpoint; 7) how to set up corrosion tests.

Living quarters will be available in nearby dormitories and student dining rooms will be open to registrants.

Those interested in marine fouling will have the opportunity to visit the William F. Clapp Laboratories on the coast at Duxbury, just north of Plymouth, Mass.

Further information will be available later, including the names of those who will give lectures. Inquiries should be addressed to Walter H. Gale, Director of Summer Session, Room 3-107, Massachusetts Institute of Technology, Cambridge 39, Mass.

MIT Schedules Two Instrument Analysis Courses During July

Two one-week specialized training programs in instrumental analysis will be offered July 9-13 and July 16-20 as part of the 1951 summer session at Massachusetts Institute of Technology, Cambridge, Mass. Prof. Walter H. Gale, director of the MIT summer session said "MIT will endeavor through the instrumental analysis courses to provide means for practicing chemists in industry to gain familiarity with the rapid and extensive changes in this field."

Dr. David N. Hume and Dr. Lockhart B. Rogers, both of the MIT department of chemistry, will conduct the courses. Facilities of the institute's instrumental analysis laboratory, operated under their direction, will be used extensively.

Purpose of the programs, according to directors, is to provide for each type of instrumental method discussed 1) an adequate grounding in the fundamental principles and theory involved; 2) knowledge of a wide variety of types of practical applications; 3) first-hand experience with available commercial instruments.

The July 9-13 program will be devoted to electrical methods of instrumental analysis and will emphasize potentiometry, polarography, conductimetry, amperometric titrations and applications of self-balancing recording potentiometers.

Optical methods of instrumental analysis, including spectrophotometry, colorimetry, fluorimetry, turbidimetry, nephelometry and flame photometry will be the subject of the July 16-20 program.

Both will consist of two-hour lecture periods and discussions and three-hour workshop each day. No academic credit will be offered.

A number of commercial instruments will be available for operation and evaluation by members of each program. Studies of the various methods will be designed to particularly help laboratory supervisors and practical analysts in selecting the best approaches to their problems. Tuition for each week will be $65.

Application forms may be obtained from Professor Gale at Room 3-107, Massachusetts Institute of Technology, Cambridge 39, Mass.

Chairmen for Texas Gas Courses Honored

Citations for their work as chairmen in the first five Short Courses in Gas Technology held at Texas College of Arts and Industries, Kingsville, Texas, have been given the following men by the college:

R. R. Suttle, Southern Gas Association, Dallas, Texas; Dean Strickland, United Gas Corp., Houston, Texas; Chester L. May, Lone Star Gas Co., Dallas; C. R. Williams, Chicago Corp., Corpus Christi, Texas, and John F. Lynch, LaGloria Corp., Corpus Christi, all chairmen of administrative committees.

Larry Ladewig, Dallas, Dr. E. Hugly, Houston; C. A. McKinney, United Gas Corp., Houston; Chester C. Young, Lone Star Gas Co., Dallas and William B. Wood, Rio Grande Valley Gas Co., Brownsville, Texas; all chairmen of utilization sections.

R. M. Hutchison, Houston Natural Gas Corp., Houston; Elton Sterrett, World Oil, Houston; W. C. McGee, Jr., Tennessee Gas Trans. Co., Houston; D. T. MacRoberts, United Gas Corp., Shreveport, La., and R. H. Ulrich, Southern Natural Gas Co., Birmingham, Ala., all chairmen of production and transmission sections.

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Chairmen Are Named for TP-16 Subcommittees

Chairmen have been named for four of the six sub-committees of Technical Practices Committee 16 on Electrolysis and Corrosion of Cable Sheaths. Irwin C. Dietze, committee chairman named the following:

TP-16A—Stray Railway Current Electrolysis, L. F. Greve, chairman, Commonwealth Edison Co., Chicago, Ill.

TP-16B — Corrosion of Lead and Other Cable Sheaths, B. B. Reinitz, chairman, The Okonite-Callender Cable Co., Inc., 730 Twenty-first Street, Paterson, N. J.

TP-16C—Cathodic Protection of Cable Sheaths, W. J. Schreiner, chairman, Cincinnati Gas and Electric Co., Cincinnati, Ohio.

TP-16D—Tests and Surveys, L. J. Gorman, chairman, Consolidated Edison Co. of New York.

TP-16E—Corrosion and Protection of Pipe Type Cables, chairman not named.

TP-16F—Non-Metallic Sheath Coatings, chairman not named.

Instrument Conference In Pittsburgh Is Set

A two-day conference on Instrumentation for the Iron and Steel Industry is scheduled for March 28-29, 1951, at Pittsburgh jointly planned by Pittsburgh Section of Instrument Society of America and Carnegie Institute of Technology. Cooperating are local chapters of American Chemical Society, American Institute of Electrical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Society for Metals, American Society for Testing Materials, the Association of Iron and Steel Engineers and the Engineers' Society of Western Pennsylvania. Further information may be secured from L. M. Susany, Carnegie Library, 4400 Forbes St., Pittsburgh, Pa.

BOOK REVIEWS

SAFETY IN ELECTRIC AND GAS WELDING AND CUTTING OPERATIONS. 44 pages, 6 x 9, paper bound. American Welding Society, 33 West 59th St., New York 18, N. Y., or American Standards Association, Inc., 70 East 45th St., New York 17, N. Y. Per Copy . . . 50c.

An American Standard on the subject title prepared by a committee sponsored by the American Welding Society under procedures of the American Standards Association. It is a revised and expanded version of the American War Standard on safety in welding and cutting. It reflects the best recommendations of welding engineers, safety engineers, equipment manufacturers, insurance organizations, labor organizations and governmental labor agencies. It covers safe installations and operation of welding equipment for all arc, gas and resistance welding processes.

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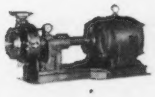

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Corrosion Problems

Questions and answers for this heading should be submitted in duplicate if possible, addressed to "CORROSION PROBLEMS", National Association of Corrosion Engineers, 919 Milam Building, Houston 2, Texas. Questions received at the address above above will be sent to E. A. Tice, The International Nickel Co., Inc., N. Y., who is acting editor of the page. All questions will become property of NACE. Questions and replies may or may not be published under this heading and may be answered either by mail directly to the person asking the information, or published under this heading, or both, at the discretion of the editorial staff. Answers to published questions are solicited. Authors of questions will remain anonymous to readers, while authors of answers may remain anonymous if they request it.

NEW QUESTION

No. 74—In connection with cathodic protection of coated and wrapper pipelines we have previously installed magnesium anodes about 10 feet off to the side of the line. Recently in a number of cases I have put packaged anodes in the same trench with the pipe, the anode being about a foot above, to the side, or under the pipe. Is there any evidence that the prepared chemical backfill will have a harmful effect on coated and wrapped pipe when placed this close to the pipe?

•

QUESTION

No. 64.—(As Revised December, 1950 issue) We should like to line a large steel hot water generator which is to operate under constant heat between 160 and 212 degrees F. A permanent lining that can be applied in the field is desired.

ANSWER A

The terminology "hot water generator" requires some clarification, but presuming that it is a tank in which water is heated or kept hot by a system of coils, or if direct fire heated the metal temperature is kept within a moderate range (i.e., less than 400 degrees F), a baked phenolic type lining as formulated by several well-known coating manufacturers would satisfy the conditions given in the question. Considerable laboratory and commercial applications substantiate this reasoning.

The field application can be done quite economically, but great care should be taken in choice of applicators as the life and effectiveness of the lining is entirely dependent upon the surface preparation, application and baking. Recommendations of the coating manufacturer in regard to number of coats, mil thickness per coat, baking time and temperature must be strictly adhered to. If properly applied the "permanence" is then dependent upon the amount of physical abuse inflicted upon the lining.—Wallace P. Cathcart, Tank Lining Corp., Oliver Building, Pitsburgh, Pa.

ANSWER B

A corrosion resistant metal lining could be installed by electric arc welding. In such an application strips of the corosion resistant alloy are welded to the steel tank, and the weld beads are usually left in the as-welded condition. Although the sheet thicknesses for linings are selected in general to meet the corossive conditions involved the minimum usually required from the standpoint of practical fabricating considerations is 0.062 inches (16 gauge USS).

Unless the application requires extremely low limits of metallic contamination, such materials as Monel, Inconel, stainless steel, and silicon bronze might be employed. A sheet lead lining might also be used.

Prior to the installation of such a lining the steel surface must be cleaned, preferably by sandblasting, or at least by disc grinding the areas to be welded—E. A. Tice, International Nickel Co., Inc., New York, N. Y.

•

QUESTION

No. 71—"Steam Spraying" of paint is a term which has recently come into use. A description of this procedure and literature regarding it is requested by the originator of this inquiry.

ANSWER

A description of this procedure will be found in the American Paint Journal, Vol. 35, No. 12, page 83 in an article "The Steam Spray Method of Product Finishing," by M. E. Herring.

Attention is also directed to U. S. Patent 2,511,797, June 13, 1950, to E. I. du Pont de Nemours & Co.—John W. Nee, Briner Paint Mfg. Co., Corpus Christi, Texas.

•

QUESTION

No. 72—Is there a cement or plastic lining or coating which will withstand constant service in hot softened or distilled water at 10 to 220 degrees F.? Applications of interest are new and old boiler feedwater tanks, condensate tanks and hot water supply tanks. A life expectancy of at least five years is desired.

ANSWER A

We have test data which show that certain baked phenolic coatings will withstand condensate water at 212 degrees F for at least five years and that such coatings have been used successfully in experimental installations in 15

(Continued on Page 15)

MIDDLE WEST C&S

COMPLETE CORROSION MITIGATION PRODUCT AND EQUIPMENT LINE

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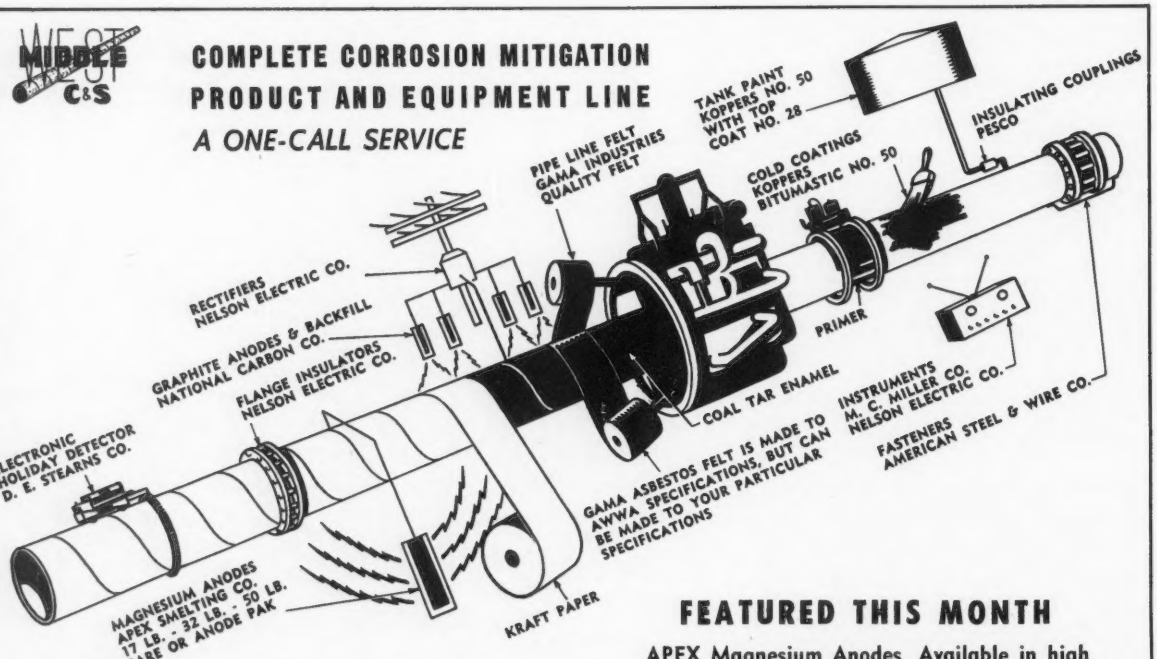
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Corrosion Problems—

(Continued from Page 14)

lb. boilers. We will be glad to correspond directly with the inquirer regarding these data.—G. W. Seagren, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, Penna.

ANSWER B

An excellent lining for this service is a baked phenolic type lining as formulated by several of the well known coating manufacturers. Many laboratory tests and commercial applications substantiate this, but one of the more striking was an accelerated test in which boiling aerated condensate water was run through a one half inch pipe at the rate of 145 feet per minute. After five years and 6 million gallons flow the pipe was cut open for examination. The total lining thickness of 3 mils was still providing 100 per cent protection.

It must be stressed that selection of the proper coating is only half the job. A successful life is completely dependent on proper surface preparation, and careful application and baking techniques. — Wallace P. Cathcart, Tank Lining Corp., Oliver Bldg., Pittsburgh, Pa.

ANSWER C

A ceramic material, known as "Elastic Porcelain" is useable for such installations. In the area within 200 miles of Detroit such applications are applied in the field by the Porc-Lin Tank Lining Co., 456 East Milwaukee Ave., Detroit, Michigan. In the area within 350 miles of Chicago, a similar process, "Rock-Tite Stone," is applied by Charles J. Riley & Sons.

Both companies have been servicing the type of tank outlined for many years, and the work is guaranteed for a minimum of five years. Further information may be obtained by contacting either of the above companies—Gordon P. Rose, Porc-Lin Tank Lining Co., Detroit, Michigan.

Clippings on Corrosion

Extracted from Current Periodicals

REFINERS HEAR MORTON ON CORROSION MITIGATION

(From Casper, Wyo., Star, Oct. 13, 1950)

B. B. Morton, development engineer for International Nickel Co., New York, will speak on "Metals and Alloys for High Sulphur, High Temperature Process Conditions," before a joint technical and industrial relations regional meeting of the Western Petroleum Refiners Association.

•

CORROSION DAMAGE TO IDLE INSTRUMENTS CITED

(From Spencer W. Va., Times-Record, Nov. 9, 1950)

Rust and corrosion cause more damage to idle instruments than the actual wear of operating them according to Waldo Bell, extension agricultural engineer at West Virginia University.

•

INHIBITOR ADDED TO ROAD SALT IN KANSAS

(From Topeka, Kans., Capital, Nov. 18, 1950)

Banox, which is not deleterious to paint, concrete, fabrics, leather or rubber will be added to salt and sand placed on icy hills and curves of Kansas highways "to cut corrosion of the resultant sludge on shiny fenders and chrome trim of cars."

•

FENDER-BODY JUNCTION HURT WORST BY ROAD SALT

(From Dallas, Texas, Times-Herald, Nov. 17, 1950)

Ralph J. Wirshing, head of the general chemistry department of General Motors Research Laboratory said the rear fender welt, or the joint between the fender and the body is the most vulnerable part of a car to salt corrosion. It's up to engineers and designers to perfect finishes and construction to combat corrosion's metal-eating work, he said.

•

PITTING CHIEF SOURCE OF SHIP HULL DAMAGE

(From Hutchinson, Kans. News-Herald, Nov. 12, 1950)

New York—Paul Field of the Bethlehem Steel Company, Quincy, Mass., told the Society of Naval Architects and Marine Engineers here that if it were not for the pitting tendency of steel it would hardly be necessary to paint and protect the under water body of a ship. The average rate at which the steel is rusted away over its entire surface is less than an eighth of an inch in 20 years he said.

Pitting corrosion may be due, Mr. Field said, to stray electric currents generated on shore and led to the ship in the water or to welding during outfitting, and also to galvanic currents resulting from coupling dissimilar metals.

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Method Is Given for Preparing Copy for Legible, Easy to Understand Lantern Slides

By IVY M. PARKER
Chairman Publications Committee

The recurring problem of indistinct projected material used to supplement oral presentation of technical papers before professional societies necessitates a review of the fundamentals leading to proper preparation of lantern slides. Technical sessions of the National Association of Corrosion Engineers are no different from those of other societies in that frequently projected material is used by persons presenting papers which has one or more of the following defects:

1. Illegibility.
2. Confused and unorganized.
3. Crowded.
4. Material not suited to projection.
5. Indistinct.

Considering these defects in sequence, it is recommended that the following measures will lead to elimination of the deficiencies:

ILLEGIBILITY—Frequently projected material is seen in which the text and descriptive material is in such small letters or such poorly reproduced letters that the whole meaning of the slide is lost. Generally it can be said that typewriter type is too small for use on slides when the last spectator viewing the projected image is 40 feet or more away from the screen. If no alternative to typewriter type is possible, pica-sized type should be used (6 lines to inch) and all letters should be capitals. Machine or hand-lettered copy is preferable.

To be visibile to a person 40 feet from the projection surface, when the image is 7 feet wide the following rule-of-thumb considerations should be weighed:

1. Letters should be written with lines 0.025 inch in width (minimum).
2. If a machine is used letters should be spaced farther apart than normally.
3. Lines of text should be separated by space equal to the depth of one line.
4. Minimum number of words should be used.

When preparing copy for graphs, the curve lines should be at least twice the thickness of the grid lines. If possible omit grid lines entirely.

In general put nothing on the copy that is not essential to the understanding of the figure.

CONFUSED and UNORGANIZED. Frequently slides are projected in which the material is so arranged the viewer is confused as to exactly what is being shown. Things which cause this most frequently are crowding too many ideas on one slide, including material unessential to the understanding of the slide and unrelated to the point being covered, and text so small or crowded the viewer cannot read it.

It usually is better to present one idea only on a slide. Oral description of the slide should be confined to what the slide shows.

CROWDING—This is one of the most frequently seen defects. It is preferable to err on the side of too much space. Lines of type, curve lines, graph lines, and all other elements projected should be separated from one another by sufficient space to prevent their "running in" to adjacent elements. Use the absolute minimum of material at all times.

MATERIALS NOT SUITED TO PROJECTION—It is an error to project complex tables. Tables should include only essential data. If possible plot data on a curve rather than present tables. Photographs in which there are distracting backgrounds, a high proportion of extraneous materials or which are otherwise complex should not be used.

INDISTINCT—An indistinct image usually is a mechanical defect. In some cases, however, the defect is in the original copy and the slide cannot be expected to be any better than the original.

General Information

1. The standard United States lantern slide measures over all 4" x 3¼". The projection area measures 3¼" by 2⅝". Copy should be prepared in proportion to the projection area. A ratio of 0.8 to 1.0 should be followed when determining vertical and horizontal dimensions of the original copy. Slides measuring 2" x 2" may also be used.
2. As a rule of thumb a person with

(Continued on Page 17)

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Method Is Given—

(Continued from Page 16)

normal eyesight should be able to read from 10 feet away the original copy for a slide intended to be projected 7 feet wide and visible to a person 40 feet from the screen, when this copy has been prepared on a sheet approximately the size of a commercial letterhead (8½x11 inches).

3. White paper and black India ink should be used. Typewriter text, if used, should be prepared from a carbon paper ribbon, or if a cloth ribbon is used, letters should be struck until they are very dense.

For those who wish to get more complete information the following references may be useful:

Corrosion, **5**, No. 11, viii-ix, (1949) Nov.

"Preparation of Lantern Slide Copy," by Carl A. Moore. *The Bulletin of the American Association of Petroleum Geologists*, **26**, No. 10, Oct. (1942).

"Hints to Authors," American Chemical Society, Washington 6, D. C. Bulletin 8.

"Preparation of Effective Lantern Slides," L. S. Bonnell, *Chem. Eng. News*, **27**, 2600 (1949) Sept. 12.

•

Advance notices of meetings or reports of proceedings will be considered for publication in CORROSION if they pertain to corrosion. CORROSION also publishes notices about corrosion courses held by schools.

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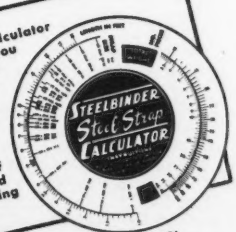

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•

Perlon Corporation is the new name of Chemco roducts Co., Inc., 7740 West 47th Street, Lyons, Ill. Management, personnel and location are unchanged.

•

Carpenter Stainless No. 20 is the title of a bulletin available from The Carpenter Steel Co., Reading, Pa. giving analysis, corrosion resistance and working characteristics of the material designed to offer superior resistance to sulfuric acid. The alloy sheet has the same analysis as Durimet No. 20 and provides the engineering advantages of a highly corrosion resistant steel combined with the fabricating and machining advantages of an 18-8 grade.

•

Gaco Drum Lining, a vinyl finish, is described in a technical data sheet available from Gates Engineering Co., P. O. Box 1711, Wilmington, Del.

•

Whitehead Metal Product's Co., Inc., has occupied a larger Baltimore warehouse at 4300 East Monument St.

•

Reilly Tar & Chemical Corp. and Lone Star Steel Corp., Daingerfield, Texas, plants were dedicated at ceremonies December 4, attended by over 300 guests. The Reilly plant, which takes all of Lone Star's coal tar output, was represented by P. C. Reilly, Jr., vice-president and C. B. Edwards, General manager. E. B. Germany, Lone Star president, represented his company. The Daingerfield plant is the eighteenth plant operated in the United States by Reilly Tar & Chemical Corp. Coal tar is piped directly from Lone Star tanks to Reilly facilities, constructed at a cost of $750,000. The Reilly plant will produce a number of products from the tar, including creosote, pipe dips, enamels and roofing pitch.

•

North American Cyanamid Ltd. will distribute in Canada products of American Cyanamid Company's Industrial Chemical Division and Coating Resins Department of the Plastics and Resins Division. The subsidiary is located at 7335 St. Lawrence Blvd., Montreal, Que. and Royal Bank Bldg., Toronto, Ont.

•

"Purification of Metal Salt Solution with Hydrogen Peroxide," a four-page data sheet, is available from Buffalo Electro-Chemical Co., Inc. Buffalo, N. Y. The article gives details on uses of hydrogen peroxide in the purification of process solutions containing metal salts. Ask for Data Sheet SP-1.

•

Magnode Products Inc. has removed its plant and offices from Brooklyn, New York to Trenton, Ohio, P. O. Box 292.

•

Primary Factors Affecting Anode Current Output is the title of a one-page bulletin, Vol. 1, No. 10 of Dowell's "The Magnesium Anode." Fundamental information on the subject is given briefly.

•

Metco News, Vol. 5, No. 5, available from Metallizing Engineering Co., Inc., 38-12 Thirtieth St., Long Island City, New York, gives details of the metal spraying with zinc .006-inch thick of the insides of two 15,000 gallon gravity sprinkler tanks in October, 1934. Inspection in June, 1950, revealed no trace of corrosion, with an average remaining thickness of zinc of .004-inch, sufficient for protection for an added 15 to 20 years, the company says.

•

Modified Tap Armour, consisting of 0.010-inch lead tape alternated with 0.012-inch sisal-kraft paper tape, covered by a single 0.010-inch steel tape and an outer protection of 0.020-inch steel tapes has been developed by Bell Telephone Laboratories. Asphalt is flooded over each subsequent layer of tape as it is applied. It was determined this could be done without destroying electrical contact between the metal tape and the sheath, necessary to protect the lead sheath from potential differences occurring when lightning strikes in the vicinity of armored cable, which sometimes are of sufficient magnitude to cause a destructive arc. This development is reported in Lead, Vol. 18, No. 3, 1950, published by Lead Industries Association, 420 Lexington Ave., New York 17, N. Y.

•

Mercast, a precision casting method using frozen mercury for the production of an intermediate matrix from booking dies is described in a bulletin by Alloy Precision Castings Co., East 45th St. and Hamilton Ave., Cleveland 14, Ohio. The process makes it possible to produce large and small castings of stainless steels, heat-resistant non-machinable metals, copper, aluminum and others with tolerances as close as plus or minus .002-inch. Stress-relieved castings may be used as-cast frequently, without machaning, manufacturers say. Because of the gas-permeability of ceramic shell molds used, singular freedom from gas and blow holes is claimed.

•

Ebasco Services Incorporated has opened new offices at 1625 I Street, N. W., Washington, D. C. W. B. Cosdon is manager.

•

The Story of Duco Finishes, a 9 x 12, 20-page and cover illustrated booklet gives detailed information about progress in all kinds of Duco coatings, with special emphasis on automobile finishes has just been issued by E. I. Du Pont de Nemours & Co., Inc., Wilmington 98, Del.

•

Carl G. Deuber has opened consulting engineering offices at 114 East 32nd St., New York 16, N. Y. He will specialize in investigations involving microbiological corrosion. Among other things, Mr. Deuber has been professor of plant physiology at Yale University, research biologist at Harvard University, was occupied with industrial research for Stauffer Chemical Co. on citric acid production by fermentation, sulfur bacteria, preservatives for spray emulsions; assistant director of Centro Research Laboratories, Inc. in charge of all biological research and development, supervised assignments from the Navy Department and Bureau of Ordnance on moisture and mildew proofing, anaerobic corrosion of gas pipe lines, evaluations of resistance of underground pipe and cable coatings, wrappers and tapes for a large public utility and is author of many articles on basic and applied research.

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by W. A. Riley

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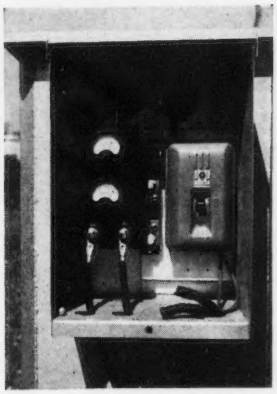
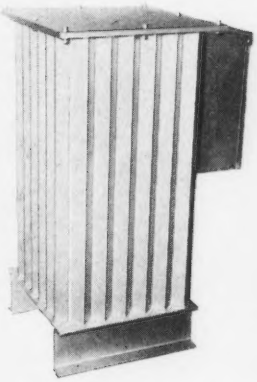
DEPENDABLE . . EFFICIENT . . LONG LIFE

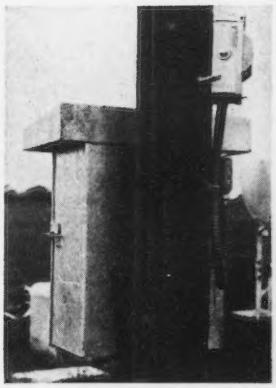
Cathodic Protection



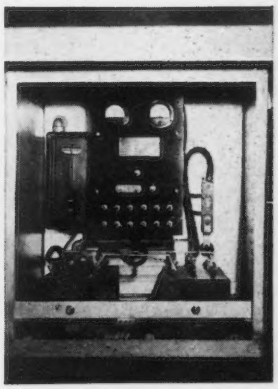
Oil-immersed, selenium rectifier —field installation showing meter and terminal box.



The NEW Westinghouse oil-immersed selenium rectifier—a 24V, 90 amp. unit just 43 inches high overall—36 gallons of oil suffice where 150 gallons were required in identical units of previous design.



Brance-Krachy air-cooled selenium rectifier in location showing pole mounting. (Method of connecting dc and ac leads optional.)



Typical unit construction—Brance-Krachy air cooled, selenium rectifier. Note sturdiness and easy accessibility.

OIL IMMERSED RECTIFIERS

Westinghouse selenium rectifiers have long been recognized for their quality featuring:

- ★ 11 ga. plate construction, bonderized—completely weather proof.
- ★ Large meter and terminal box easily accessible for making connections and reading meters.
- ★ AC circuit breaker equipped with heater type thermal overload relays.
- ★ Unitized construction of power unit for easy removal and inspection.

AIR-COOLED RECTIFIERS

New design features in Brance-Krachy air-cooled, selenium rectifiers are scaled to meet the demand for compactness and ruggedness in construction in this type of unit. These rectifiers are unsurpassed in quality, yet economical in terms of initial investment and years of trouble free performance. They feature:

- ★ 11 ga. plate construction—bonderized, or hot-dip galvanized after fabrication — case completely insect proof.
- ★ Fansteel selenium stacks—normally derated for operation at 60° ambient temperature for extra stack life.
- ★ AC starter—heater type overload protection.
- ★ Heavy duty transformer construction with strap type secondary top changer. We will build the unit to meet your requirements.

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ADD VALUABLE YEARS OF LIFE AND SERVICE WITH B-K PACKAGED PROTECTION UNITS

Brance-Krachy complete package-type protection units include either copper oxide or selenium, air-cooled or oil-immersed rectifiers, underground "trench wire," graphite and carbon anodes and coke breeze backfill. Complete cathodic protection installations sent to your job as a unit. ALCOA magnesium anodes and M. C. MILLER'S MULTI-COMBINATION METERS in stock. We have all accessories for installing any type cathodic protection installation.

WE WILL BUILD THE UNIT TO MEET YOUR REQUIREMENTS

COMPLETE CATHODIC PROTECTION EQUIPMENT — BK

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ALUMINUM COMPANY OF AMERICA

Pittsburgh, Pa.

ADVANCE NEWS ABOUT THE NACE CONFERENCE IN NEW YORK

"march in new york" Program Is Diversified and Interesting

By L. B. DONOVAN,
General Chairman,
1951 Conference Committee

Now that virtually all phases of preparation for the 1951 Conference and Exhibition, to be held March 13 through 16 at the Hotel Statler in New York City, rapidly are reaching the final stages it is only fitting to express appreciation to those who have worked throughout the year for the success of the Association and the forthcoming Conference.

L. B. Donovan

Due to the excellent work of Norman Hackerman and his Technical Program Committee a diversified program of the highest order has been planned and organized. Not only will this program be of general interest to all association members but it should be of major technical importance to the field of corrosion engineering.

Ed Seidel, chairman of the Exhibition Committee, and his group have done an outstanding job not only in planning booth arrangements and layout but in selling all available space in record-breaking time.

In any large undertaking of this type the amount of loose ends and miscellaneous detail is staggering. In this respect the efforts of the Local Arrangements Committee under Chairman H. L. Hamilton in coordinating the countless details that crop up plays a most important part, contributing greatly to the success of a conference of this scope.

As usual Central Office has done an excellent job throughout in assisting all committees involved.

The unselfish contribution of time and effort by committee and subcommittee members concerned is indicative of the seriousness of purpose and intent with which they have tackled their tasks and shouldered their responsibilities, all of which should make the 1951 Conference the greatest and most successful ever.

The most fitting reward for association members who have worked long and hard to prepare for the conference is, of course, a commensurate turn-out on the part of the general membership.

However, even more important is the fact that it is to the benefit of all Association members to make every effort to avail themselves of the wealth of information on the wide variety of technical subjects, materials, apparatus and services that will be concentrated at the annual conference. In these critical times no means of conserving our country's industrial potential should be overlooked.

Last, but not least, here again is a chance for all association members to get together, renew friendships and meet personally many of those people who are outstanding authorities and leaders in the field of endeavor for which our Association was organized; namely, the advancement of corrosion control techniques and practices.

MEMBERSHIP CARDS AVAILABLE

Association members in good standing will be issued on request a membership card in the National Association of Corrosion Engineers. Address requests to A. B. Campbell, Executive Secretary, 919 Milam Building, Houston 2, Texas.

march in new york

. . . The largest and most comprehensive exhibit of materials and apparatus in N.A.C.E. history.

. . . A fascinating program for the ladies includes attending a United Nations meeting, visit to a trans-Atlantic liner, Fashion Show at the Hotel Pierre, Tea at the Statler Skytop Roof, Cosmetic Show at Radio City Rainbow Room, Television and Radio Shows and many other features.

. . . And a main conference program packed with subjects of critical importance discussed by outstanding experts and leaders in the industry.

YOU CAN'T AFFORD TO MISS THE . . .

1951 CONFERENCE AND EXHIBITION

NATIONAL ASSOCIATION OF CORROSION ENGINEERS

HOTEL STATLER • MARCH 13 • 14 • 15 • 16

Eleven Symposia, Two Round Tables Are Scheduled

Following is the technical program scheduled for the 1951 NACE Conference in New York, with officials of the various symposia, corrected through January 10, 1951:

March 13—2 to 3 p.m.

Corrosion Principles Symposium

Chairman: H. H. Uhlig, Massachusetts Institute of Technology, Cambridge, Mass.

Physical Chemical Aspects of Corrosion Inhibition, Norman Hackerman, University of Texas, Austin.

March 13—3:10 to 5 p.m.

Water Industry Symposium

Chairman: R. R. Ashline, Dept. of Water and Power, Los Angeles, Cal. Co-chairmen: A. Damiano, Hackensack Water Co., Weehauken, N. J., and Thomas M. Riddick, Consulting Engineer, 369 149th St., New York, N. Y.

Interconnection of Pipe Lines Having Various Coatings, David Hendrickson, East Bay Municipal District, Oakland, Cal.

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Having new tanks treated by NATASCO is the sure way of getting the ultimate in use from them over a long period of years. Old tanks will also give many years additional service by receiving the proper NATASCO treatment. NATASCO protects the steel surface from all corrosion. Due to the increasing shortage of steel, and its rising cost, NATASCO service provides substantial savings.

SAVES OIL

Evaporation of volatile fractions and loss through leakage has accounted for smaller profits in many oil firms. In most cases *this loss could have been prevented if the tanks had been serviced by NATASCO.*

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If you have added additional years of service life to your tanks and have eliminated loss by evaporation and leakage, *you have added profits to your business.*

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Lease Tank Service—West Texas Area: Williams Construction Company, Odessa, Texas

California Representative: Coast Contractors, Ltd. 4636 E. Slauson, Maywood, Cal.

Corrosion Control of Domestic Hot Water Heaters by Magnesium Anodes, H. A. Robinson, Dow Chemical Co., Midland, Mich.

Corrosion Control of Recirculating Water Systems with Calgon, G. B. Hatch, Calgon Inc., Pittsburgh, Pa.

Pipe Line Industry Symposium

Chairman: I. B. Tietze, Phillips Pipe Line Co., Bartlesville, Okla. Co-chairmen: Wm. E. Huddleston, Huddleston Engineering Co., Bartlesville, Okla. and S. S. Smith, Shell Oil Co., New York, N. Y.

Coating Evaluation Tests on 335 miles of Asphalt Mastic Coated Pipe, Don Miltner, Socony-Vacuum Oil Co., Wichita, Kans.

Criteria for the Cathodic Protection of Steels in Soils, W. J. Schwerdtfeger and O. N. McDorman, Bureau of Standards, Washington, D. C.

Economics of Rectifier Installations for Cathodic Protection of a Bare Pipe Line, D. C. Glass, Pure Transportation Co., Chicago, Ill.

March 14—9 a.m. to 12 noon

Boiler Feedwater Symposium

Chairman: John W. Ryznar, National Aluminate Corp., Chicago. Co-chairman: Melvin A. Hanson, Gulf, Mobile & Ohio Railroad, Bloomington, Ill.

Prevention of Corrosion and Metal Attack in the Steam Water Cycle of the Steam Power Plant, Frederick G. Stroub and Henry D. Ongman, University of Illinois, Urbana.

Iron Oxide on Water Side of Tube in a Cyclone-Fired Pressurized Steam Generator, M. E. Brines and F. N. Alquist, Dow Chemical Co., Midland, Mich.

Prevention of Standby Corrosion in Power Plants, Leonard Highley, Jr. and W. R. Schnarrenberger.

(One more paper to be added)

Chemical Industry Symposium

Chairman: W. Z. Friend, International Nickel Co., Inc., New York. Co-chairmen: M. G. Fontana, Ohio State University, Columbus and F. A. Rohrman, University of Colorado, Boulder.

Materials for Handling Sulfuric Acid, Technical Practices Subcommittee TP-5A, Chairman S. W. Shepard, American Cyanamid Co., New York.

Sub-surface Corrosion by Alkaline Solutions, Technical Practices Subcommittee TP-5C, Chairman H. W. Schmidt, Dow Chemical Co., Midland, Mich.

Corrosion by Some Organic Acids and Related Compounds, H. O. Teeple, International Nickel Co., Inc., New York. (Sponsored by Technical Practices Sub-committee TP-5D.)

Corrosion in the Ammonolysis of Aliphatic Chlorides, R. S. Treseder and R. F. Miller, Shell Development Co., Emeryville, Cal.

March 14—2:30 to 5 p.m.

Transportation Industry Symposium

Chairman: Merritt A. Williamson, Pullman-Standard Car Manufacturing Co. Hammond, Ind. Co-chairmen: Otto E. Kirschner, American Airlines, New York and Joseph Winlock, The Budd Co., Philadelphia.

(Continued on Page 24)

Additive for light petroleum products

CHECKS CORROSION

TESTS PROVE that Santolene C stops rust in fuel oil. Results of tests with various concentrations of the additive are shown above. (A) No Santolene C. (B) 10 ppm Santolene C. (C) 20 ppm Santolene C.

One of the latest Monsanto's petroleum additives is Santolene C—developed as a metal corrosion inhibitor for use in light petroleum products. It is highly effective under both static and dynamic conditions.

Santolene C is very economical in application, since the addition of only a minute percentage of Santolene C is usually sufficient to greatly minimize, if not eliminate, rust formation. For example—the estimated cost of inhibiting rust in a 42-gallon barrel of fuel oil is generally less than 2/10 cents ($0.002).

The physical properties of Santolene C, as well as results of laboratory and field tests, are described and illustrated in Monsanto Technical Bulletin No. O-62. Copies will be sent on request, along with such added information as may be required. MONSANTO CHEMICAL COMPANY, Organic Chemicals Division, 1700 South Second Street, St. Louis 4, Missouri.

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City.....*Zone*.....*State*.....

SERVING INDUSTRY . . . WHICH SERVES MANKIND

Eleven Symposia—

(Continued from Page 22)

Corrosion of Railroad Hopper Car Body Sheets, B. J. Kelly, United States Steel Corp., Pittsburgh.

Prevention of Corrosion on Railroad Track and Equipment from Brine Drippings, G. M. Magee, Association of American Railroads, Chicago.

Prevention of Corrosion in Naval Aircraft, E. N. Promisel and G. S. Mustin, Bureau of Aeronautics, Department of the Navy, Washington, D. C.

Corrosion Problems of Motor Coach Construction, K. L. Raymond, General Motors, Corp., Truck and Coach Div., Pontiac, Mich.

Protective Coatings Symposium

Chairman: Kenneth Tator, Coraopolis, Pa. Co-chairmen: C. G. Munger, American Pipe and Construction Co., South Gate, Cal.; G. G. Sward, National Paint, Varnish and Lacquer Assoc., Washington, D. C. and R. P. Devoluy, C. A. Woolsey Paint and Color Co., Inc., New York. (Sponsored by Technical Practices Committee TP-6)

Glass-lined Steel in the Chemical, Food and Beverage Industries, Technical Practices Subcommittee TP-6H, S. W. McCann, Pfaudler Mfg. Co., Rochester, N. Y.

Chlorinated Rubber Corrosion-Resistant Coatings, F. R. Shankweiler, G. N. Bruxelles and R. E. Whitney, Hercules Powder Co., Wilmington, Del.

Some Effects of Cathodic Protection on Conventional Paints, L. F. Sudrabin, F. J. LeFebvre, Electro Rust-Proofing Corp. Belleville, N. J. and D. L. Hawke, A. J. Eickhoff, Research Laboratories, National Lead Co., Brooklyn, N. Y.

(One more paper to be added)

March 15—9 a.m. to 5 p.m.

Oil and Gas Industry Symposium

Chairman: T. S. Zajac, Shell Oil Co., Houston. Co-chairmen: H. E. Waldrip, Gulf Oil Corp., Houston and E. Q. Camp, Humble Oil & Refining Co., Baytown, Texas.

Bacterial Casing Corrosion in the Ventura Field, Keith Doig, Shell Oil Co., ventura, Cal., and Aaron Wachter, Shell Development Co., Emeryville, Cal.

Control of Sour Crude Corrosion in Kansas Production Operations, L. C. Case, Gulf Oil Corp., Tulsa.

High Pressure Sweet Oil Well Corrosion, H. L. Bilhartz, Atlantic Refining Co. Dallas.

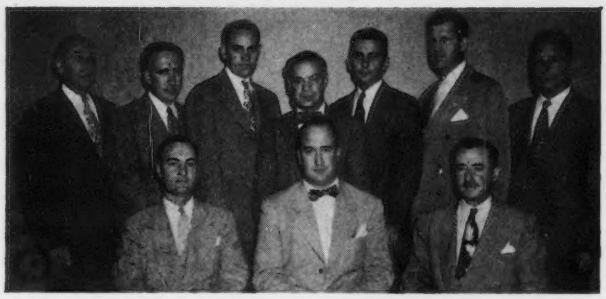
Some Applications of Organic Corrosion Inhibitors in the Petroleum Industry, Chas. M. Blair, Jr., Petrolite Corp., St. Louis, Mo.

Literature Survey on Corrosion in Neutral Unaerated Oil Well Brines, Harry R. Copsin, International Nickel Co., Inc., Bayonne, N. J.

Cathodic Protection Symposium

Chairman: Sidney E. Trouard, New Orleans Public Service, Inc., New Orleans, La. Co-chairmen: A. W. Peabody, Ebasco Services, Inc., Jackson, Miss. and Y. W. Titterington, Dowell, Inc., Tulsa, Okla.

Effectiveness of Cathodic Currents in Reducing Crevice Corrosion and Pitting in Sea Water, T. P. May, International Nickel Co., Inc., and H. A. Humble, Dow Chemical Co., Midland, Mich.



Some members of the 1951 Conference and Exhibition Committee and Local Arrangements Committee are pictured above. Standing, left to right, W. Aretz, hospitality; G. Hull, Jr., printing; T. May, Conference coordination; M. Bermann, transportation; R. Young, entertainment; F. LeFebvre, hotel and meeting rooms; F. Kuhlman, registration information. Seated, left to right, E. R. English, publicity and secretary; H. L. Hamilton, chairman of local arrangements committee and assistant general chairman; L. B. Donovan, general chairman. Other members of Conference committees are listed elsewhere in this issue.

Cathodic Protection at Steam-Electric Generating Stations, James Collins, Ebasco Services, Inc., New York.

A Field Investigation of Cathodic Protection in Glass-Lined and Galvanized Water Heaters, W. A. Deringer and F. W. Nelson, A. O. Smith Corp., Milwaukee, Wis.

Potential Measurements for Estimating Protective Current Requirements, Scott Ewing, Carter Oil Co., Tulsa, Okla.

March 15—2:30 to 5 p.m.

Electrical and Communications Industry Symposium

Chairman: K. G. Compton, Bell Telephone Laboratories, Murray Hill, N. J. Co-chairmen: W. C. Honecker, Indiana Bell Telephone Co. Indianapolis, Ind. and H. N. Trueblood, Dobbs Ferry, N. Y.

Corrosion Problems of Rural Power Distribution, Orville Zastrow, Rural Electrification Administration, Washington, D. C.

Tower Footing Corrosion, Walter J. and John D. Piper, Detroit Edison Co., Detroit, Mich.

Cell Potentials and Currents, Robert Pope, Bell Telephone Laboratories, Murray Hill, N. J.

Effect of Packaging on Corrosion of Zinc-plated Equipment, K. G. Compton, S. M. Arnold and A. Mendizza, Bell Telephone Laboratories, Murray Hill, N. J.

Filamentary Growths on Metal Surfaces, "Whiskers," K. G. Compton, and A. Mendizza, S. M. Arnold.

Industrial Use of Corrosion Inhibitors Symposium

Chairman: Aaron Wachter, Shell Development Co., Emeryville, Cal. Co-chairmen: Morris Cohen, National Research Council, Ottawa, Canada and John Ryznar, National Aluminate Co.

Water Treatment Is an Art, G. N. Andrews, Shell Oil Company, Wood River, Ill.

Sodium Hydroxide as Inhibitor of Pitting in 18-8 Stainless Steel, J. W. Matthews, Creole Petroleum Corp., Caripito, Venezuela and H. H. Uhlig, MIT, Cambridge.

Plant Results in Control of Return Condensate Line Corrosion by the Filming Amines, H. Lewis Kahler, W. H. and L. D. Betz Co., Philadelphia.

Rosin Amine-Ethylene Oxide Condensates as Corrosion Inhibitors for Mild Steel in Hydrochloric Acid, Edward A. Bried and Harry M. Winn, Hercules Powder Co., Wilmington, Del.

Dicyclohexyl Ammonium Nitrite, a Volatile Inhibitor for Corrosion Protective Packaging, A. Wachter, T. Skei and N. Stillman, Shell Development Co., Emeryville.

March 16—9 a.m. to 12 noon

Round Table of General Corrosion Problems

Chairman: F. L. LaQue, International Nickel Co., Inc., New York.

Round Table on Pipe Line and Underground Corrosion

Chairman: R. L. Bullock, Interstate Oil Pipe Line Co., Tulsa.

•

Corrosion Abstracts in CORROSION now are published on pages numbered serially through the calendar year for the convenience of those who bind this part of the magazine for reference purposes.

•

H. J. Henke has been named superintendent of the East St. Louis, Ill. Bitumastic protective coatings plant of Koppers Company, Inc. He formerly was superintendent of the Verona, Pa. Tar Products Division.

FREE ***Preprints and Reprints While Supply Lasts***

Corrosion Problems Related to Air Transport Aircraft, **by Otto E. Kirchner and Fred M. Morris, American Airlines. A paper prepared for presentation at NACE meeting, St. Louis, Mo., April, 1950.**

The Influence of Stress on Corrosion, **by Julius J. Harwood, Office of Naval Research, Washington, D. C. Reprinted from CORROSION, Vol. 6, No. 8 and and 9 (1950). A paper presented at the NACE meeting, St. Louis, Mo., April, 1950.**

Address your request to: Norman E. Hamner, Managing Editor, Corrosion, 919 Milam Bldg., Houston 2, Texas.

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RUST-OLEUM is the practical answer to a wide range of rust problems. For more than a quarter of a century **RUST-OLEUM** has been proved under severe conditions of weather, fumes, salt air, salt spray, and other rust producing conditions.

Nationally known users* in almost every field of industry have found **RUST-OLEUM** the economical way to stop rust and retard further rust.

An exclusive formula, **RUST-OLEUM** gives outstanding protection that cuts maintenance costs. It's tough, pliable film dries to a firm finish that protects against rust.

Even where rust has already started, **RUST-OLEUM** can be applied effectively and economically. It is only necessary to remove all rust scale and loose rust. **RUST-OLEUM** merges the remaining rust into a rust-resisting durable coating that adds years of use to many metal surfaces, indoors or outdoors.

RUST-OLEUM is excellent for application in sealed or inaccessible spaces where condensation due to temperature changes breeds rust—and where it is not possible or practical to sandblast or clean to bright metal.

Available in a large selection of colors, including aluminum and white, **RUST-OLEUM** beautifies as it protects.

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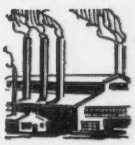

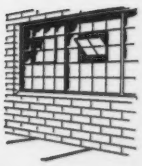

See Our Exhibit at Hotel Statler, March 13-16—Booth No. 32

RUST-OLEUM CORPORATION

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Names of Conference Committee Members Are Listed

Following are the names of the persons in the committees responsible for the 1951 NACE Conference in New York:

General Conference Committee

Chairman: L. B. Donovan, Consolidated Edison Co. of New York, Inc., New York City.
Secretary: E. R. English, H. C. Price Co., Philadelphia, Pa.

Technical Program Committee

Chairman: Norman Hackerman, University of Texas, Austin, Texas.
Vice-Chairmen: R. L. Bullock, Interstate Oil Pipe Line Co., Tulsa, Okla.; G. W. Seagren, Mellon Institute, Pittsburgh, Pa., and Aaron Wachter, Shell Development Co., Emeryville, Cal.

Exhibition Committee

Chairman: G. E. Seidel, Amercoat Corp., Chicago, Ill.
Members: Clark A. Bailey, Johns-Manville Sales Corp., New York City; Bo Bardsley, Crutcher-Rolfs-Cummings, Inc., Tulsa, Okla. and Milton Bowen, Hill-Hubbell Div., General Paint Corp., Cleveland, Ohio.

Local Arrangements Committee and Sub-Committees

Chairman: H. L. Hamilton, Keystone Pipe Line Co., Philadelphia, Pa.

Registration and Information

Chairman: F. E. Kulman, Consol. Edison Co. of N. Y., New York.
Members: H. F. Brown, New York, New Haven and Hartford Railroad, New Haven, Conn.; G. J. Christ, New York Telephone Co., Brooklyn, N. Y.; W. L. Crosby, Consolidated Edison Co. of N. Y. Inc., New York; H. W. Dieck, Long Island Lighting Co., Mineola, N. Y.; W. F. Fair, Koppers Co. Inc., Westfield, N. J.; E. A. Gray, Pipe Protection Service, Inc., Elizabeth, N. J.; K. A. Gruber, Chemical Fire and Rust Proofing Corp., New York; A. K. Joecks and H. F. Koester, Consol. Edison Co., of N. Y.; B. C. Lattin, Westchester Lighting Co., Mount Vernon N. Y.; E. C. Reichard, American Smelting & Refining Co., Barber, N. J.; E. R. Saul, New York Telephone Co.; E. A. Tice, International Nickel Co., Inc., New York; H. W. Wahlquist, Ebasco Services, Inc., New York, N. Y.

Ladies' Committee

Chairman: Mrs. Beatrice Bailey, Consol. Edison Co. of N. Y.
Members: Mrs. Samuel I. Croney, Havertown, Pa.; Mrs. Robert R. Pierce, Pennsauken, N. J.; Mrs. Samuel B. McWhorter, New Brunswick, N. J.

Transportation Committee

Chairman: M. Bermann, Brooklyn Union Gas Co., Brooklyn, N. Y.
Members: Frank M. Ruffing, Magnode Products, Inc., Brooklyn; A. E. Archambault, N. Y. Central Railroad, New York.

Hotel and Meeting Room Committee

Chairman: F. J. LeFebvre, Electro Rust-Proofing Corp., Belleville, N. J.
Members: R. T. Browning, Electro Rust-Proofing Corp., Belleville, N. J.; William B. Cameron, Brooklyn Union Gas Co.; T. T. Quigley, M. J. Schiff, T. E. Brady and Walter Obermann, Electro Rust-Proofing Corp.; Arnold J. Eickhoff, and David L. Hawke, National Lead Co., Brooklyn; James L. Davidson, Long Island Lighting Co., Garden City, L. I.; T. J. Eberhardt, Subox, Inc., Hackensack, N. J.; William L. Hale, The Debevoise Co., Brooklyn; Edward J. Higgins, East Orange, N. J.; D. O. Lackmund, Amercoat Corp., Newark; V. J. Scarola, Tapecoat Co., New York.

Printing Committee

Chairman: G. C. Hull, Jr., Anglo-American Varnish Co., Newark.
Members: W. D. Mathers, Aluminum Co. of America, New York; W. G. Pittman, Hackensack, N. J.

Conference Coordination

Chairman: T. P. May, International Nickel Co., Inc., New York.
Members: J. Pat Casey, Jr., The Crane Co., Chicago; W. W. Palmquist, Union Carbide & Carbon Corp., Cleveland; W. F. Gross, Tret-o-Lite Co., Webster Grove, Mo.; W. H. Aretz, W. A. Briggs Bitumen Co., Philadelphia; J. M. Bialosky, U. S. Steel Corp., Pittsburgh; J. E. Shields, Alox Corp., Niagara Falls; L. G. Von Lossberg, S. T. Powell, Baltimore; E. P. Tait, Alloy Steel Prod. Co., Atlanta, Ga.; T. D. Williamson, Jr., T. D. Williamson, Inc., Tulsa; T. F. P. Kelly, James E. Mayor Co., Houston; H. Wilbanks, Jr., Gas Dept., City of Corpus Christi; D. L. Burns, Gulf Oil Corp., Port Arthur, Texas; R. S. Treseder, Shell Development Co., Emeryville, Cal.; Pat H. Miller, Texas Eastern Trans. Corp., Shreveport, La. Section Chairmen: Guy G. Crawford, Service Engineers, Inc., Midland, Texas; DeLasso Loos, Cool & Stilley Eng., Midland; H. R. Brough, Mountain Fuel & Supply Co., Salt Lake City; D. T. Jones, Pacific Telephone & Telegraph Co., North Hollywood, Cal.

Entertainment Committee

Linden Stuart, Jr., Barrett Division, Allied Chemical & Dye Corp., New York; Robert J. Young, Hill, Hubbell and Company, Ridgewood, N. J.; Robert de-Laski, W. A. Briggs Bitumen Co., New York City; W. F. Yahnker, Glasfloss Corp., Hicksville, L. I.; Gordon W. Brown, Cheeseman-Elliott Corp., Brooklyn.

Publicity Committee

Chairman: E. R. English, H. C. Price Co., Philadelphia.
Members: George Diehlman, National Lead Co.; H. F. McConomy, Atlantic Refining Co., Philadelphia.

Hospitality Committee

Chairman: W. H. Aretz, Briggs Bitumen Co., Philadelphia.
Members: H. H. Bennett, Socony-Vacuum Oil Co. Inc., Paulsboro, N. J.; G. E. Boyd, Koppers Co., Inc., New York; Edward G. Brink, American Viscose Corp., Marcus Hook, Pa.; J. P. Casey, Jr., Crane Co., Chicago; Samuel I. Croney, Atlantic Refining Co., Philadelphia; R. P. Devoluy, C. A. Woolsey Paint and Color Co., New York; James E. Dodgen, Pennsylvania Salt Mfg. Co., Philadelphia; T. J. Eberhardt, Subox, Inc., Hackensack; K. W. Grader, Ralph V. Rulon, Inc., Philadelphia; W. F. Gross, Tret-O-Lite Co., St. Louis, Mo.; K. G. Hall, Pipe Protection Service, Inc., Elizabeth, N. J.; J. C. Howell, Public Service Elec. & Gas Co., Maplewood, N. J.; H. E. Johnston, Dearborn Chemical Co., New York; Frank Kahn, Philadelphia Electric Co.; J. F. Mason, International Nickel Co., New York; Sam B. McWhorter, New Brunswick, N. J.; Ralph G. Mensch, Pittsburgh Coke & Chemical Co., Pittsburgh; J. D. Munro, Standard Oil Development Co., Linden, N. J.; W. W. Palmquist, National Carbon Div., Union Carbide and Carbon Corp., Cleveland; Robert R. Pierce, Pennsylvania Salt Mfg. Co., Philadelphia; William Powers, Lukens Steel Co., Coatesville, Pa.; James E. Shields, Alox Corp., Niagara Falls; Edward S. Siegel, Minnesota Mining & Mfg. Co., Ridgefield, N. J.; H. O. Teeple, International Nickel Co., New York; R. S. Treseder, Shell Development Co., Emeryville; Lewis G. Von Lossberg, Baltimore; T. D. Williamson, Jr., T. D. Williamson, Inc., Tulsa; E. H. Wyche, Lukens Steel Co., Coatesville, Pa.; W. R. Briggs, W. A. Briggs Bitumen Co., Philadelphia.

Informing Members Was Publicity Aim

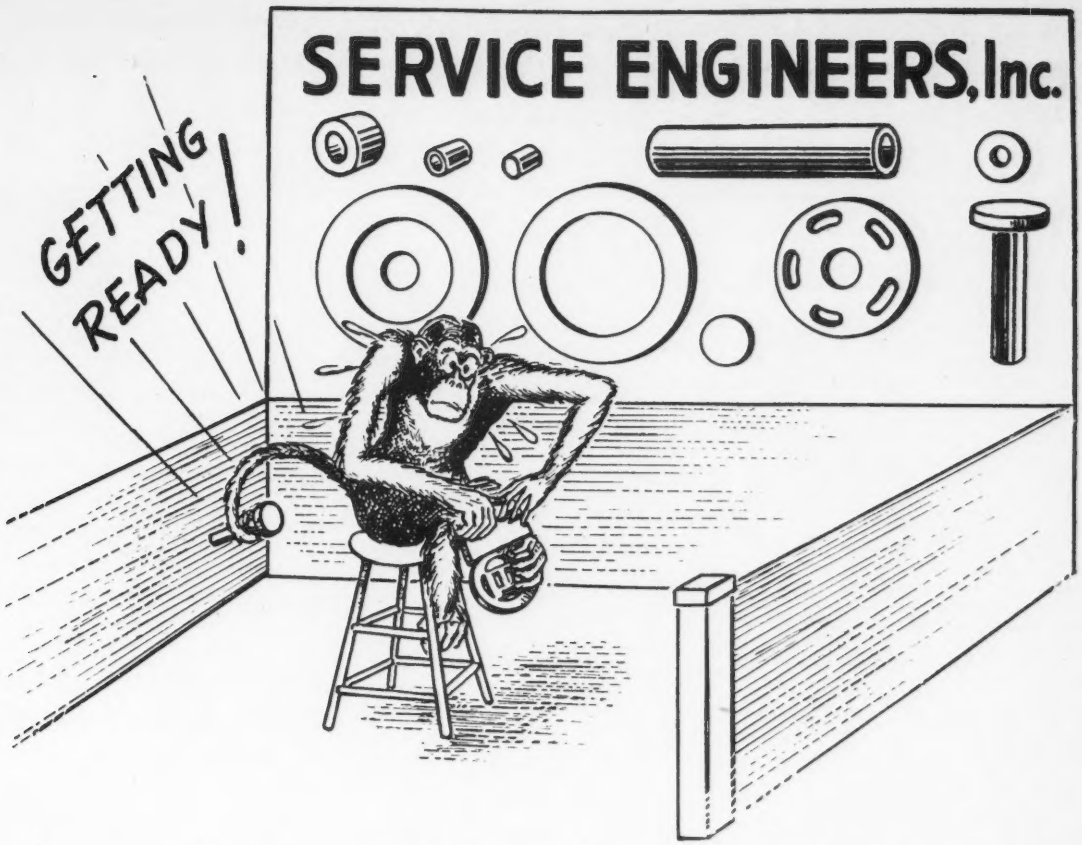
Much of the paper work required to coordinate the activities of the committees responsible for the various phases of the 1951 General Conference and Exhibition has been handled by E. R. English, Secretary of the General Conference Committee. An effort has been made to keep all officers of the Association, as well as those actively participating in the Conference activities, informed of the progress being made.

E. R. English

In addition news releases have been distributed to trade and technical journals, as well as to CORROSION magazine, by the Publicity Committee also headed by Mr. English. Advance newspaper publicity is being scheduled, as well as a series of press conferences to be held during the Conference.

Names of Decorator, Cartage Firms Given

Strauss Decorating and Exposition Co., Inc., 480 Lexington Ave., New York 17, N. Y. has been named official decorator for the "March in New York" conference March 13-16 and W. J. Casey Trucking & Rigging Co., Inc., 600 Bergen St., Brooklyn 17, N. Y., has been named official cartage company. Exhibitors are asked to communicate directly to these firms for information and services within their respective provinces.



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AT THE MARCH 13-16, 1951 N.A.C.E. ANNUAL CONFERENCE

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Local Arrangements Chairman H. L. Hamilton Forecasts Successful 1951 NACE Conference

Following the meeting of the Local Arrangements Committee and sub-committees at the Hotel Statler, New York, on January 4, Chairman H. L. Hamilton reported that plans for the 1951 General Conference and Exhibition have developed to a point where the success of the meeting is assured.

He expressed great appreciation for the manner in which the chairmen and members of the committees working with him have cooperated in handling the many details required for the successful presentation of so elaborate a meeting, at which an attendance of approximately 1200 is expected.

H. L. Hamilton

The Registration and Information Committee headed by F. E. Kulman has already announced details of advance registration, to be used this year for the first time by this organization. In addition to the Registration Desk at the Conference, there will be an Information Booth, with telephone service and a public address system, so that members may be reached by calls through the Statler Hotel switchboard.

Ladies' Program Given

Mrs. Beatrice Bailey's Ladies' Committee promises an outstanding program of entertainment for the ladies, covering the real highlights of New York interests. The Ladies Lounge, adjacent to the Conference area will be the center of activity and a social gathering spot. Activities will commence with a tea, Monday afternoon; on the following days there will be radio and television studio visits, tea at the Rainbow Room, lunch and fashion show in the Cotillion Room of the Hotel Pierre, a visit to the United Nations meetings, and tea aboard a trans-Atlantic liner.

Information obtained by M. Bermann as head of the Transportation Committee has been forwarded to local coordinators, to assist members in making use of the various regular and special facilities available on air and rail lines.

The assignment of accommodations for the many meetings to be held—business, committee, program, lounges and special requirements for information booths, etc.—has been coordinated by the Hotel & Meeting Rooms Committee, of which F. J. LeFebvre is chairman. Close cooperation with the Statler Hotel staff will assure that suitable facilities are available as needed.

Advance Program Mailed

The printing requirements for the annual Conference are many and varied, and these have been handled by the Printing Committee. G. C. Hull, Jr., chairman, has provided for an advance program mailed early in January, the advance registration forms, the complete Conference program, a ladies souvenir program, and numerous tickets, letters, etc., all required as service items.

T. P. May organized a Committee of Conference Coordination, enlisting the aid of members in as many local Regions and Sections as possible, furnishing to them advance information on the Conference features including the many innovations for 1951. In turn, local groups have been asked to comment on plans so that this Conference will meet with general approval.

The Entertainment Committee, headed by Linden Stuart, Jr., has made arrangements so that the Fellowship Hour sponsored by the exhibitors will provide in every way for the pleasure of the guests. This has also been the aim in planning for the banquet, where 500 guests will be served an excellent dinner followed by a fast-moving show of Broadway talent. In addition, this committee has lent assistance to the Ladies Committee to provide for the entertainment of the ladies who will be guests at the Conference.

Hospitality Committee Formed

Chairman W. H. Aretz has lent his well known talents to the organization of a Hospitality Committee which will make every effort to provide for the comfort and pleasure of those attending the Conference. Staffed by members from almost every local group, the committee will extend a continuing welcome to the Conference.

Efforts have been made by the Publicity Committee headed by E. R. English to publicize the work of the conference committees, and the features and innovations to be introduced, through CORROSION, and magazine and trade and technical journals throughout the country. All officers and other members of the Association actively participating in Conference planning have been furnished with up-to-the minute information.

Without the active cooperation of A. B. Campbell, Executive Secretary, of Norman Hamner, Managing Editor of CORROSION, and of other members of the Houston staff, much of the correlation of committee work would be difficult. The successful outcome of the plans of the Local Arrangement Committees will be the result of genuine cooperation by all who have been asked to participate.

Powerful Ultrasonic Generator Being Made

Brush Development Company is building an experimental two kilowatt ultrasonic generator, the first such generator of sufficient power to be able to accomplish on a pilot plant scale certain things so far achieved only under laboratory conditions. This information was given by John W. Butterworth, director of hypersonics at the Brush company during a symposium at the 43rd Annual Meeting of the American Institute of Chemical Engineers at Columbus, Ohio. Generators of unlimited power can be built, Mr. Butterworth reported, as a result of the development of a ceramic material which gives off high intensity sound waves when excited electrically.

Among the things these waves are known to accomplish is preparation of emulsions, such as paint, in which after irradiation, the pigment no longer settles out of the mixture.

Varied Transportation Needs Will Be Met

The Transportation Committee for the 1951 General Conference and Exhibition, headed by Mr. M. Bermann, is arranging all details of transportation required for the many and varied entertainment features being provided for the ladies attending the Conference.

M. Bermann

In addition, much work has been done by this committee in obtaining information concerning schedules, rates, availability of reduced-rate group accommodations, etc. on air and rail lines from all parts of the country to New York. This information has been made available to members through the Conference Coordinators appointed in each Region and Section. If other transportation information is desired, the coordinators will consult Mr. Bermann.

Advance Registration Forms Sent Members

Advance Registration forms have been mailed to all members of the National Association of Corrosion Engineers so that those who wish to do so may register in advance of the opening of the 1951 Conference and Exhibition March 13. The mailing consisted of a covering letter, an advance registration form and a hotel reservation form.

Those who register in advance will receive from Central Office NACE, 919 Milam Bldg., Houston, Texas, a receipted card, which, when presented at the desk for Advance Registrants will entitle the bearer to receive in one package badges, programs, banquet tickets, and or other papers. Considerable time will be saved by advance registration, the committee believes. Full details may be found on Page 7, January CORROSION.

Reservations for hotel space are made to the hotel itself.

Usual Registration Facilities to Be Ready

The usual facilities for registration will be available at Hotel Statler, New York City for those who do not register in advance. The registration desk at the hotel will open at 9 a.m. Monday, March 12 and will be available daily through Thursday, March 15.

Persons planning to attend committee meetings Monday will find it will save time to register Monday.

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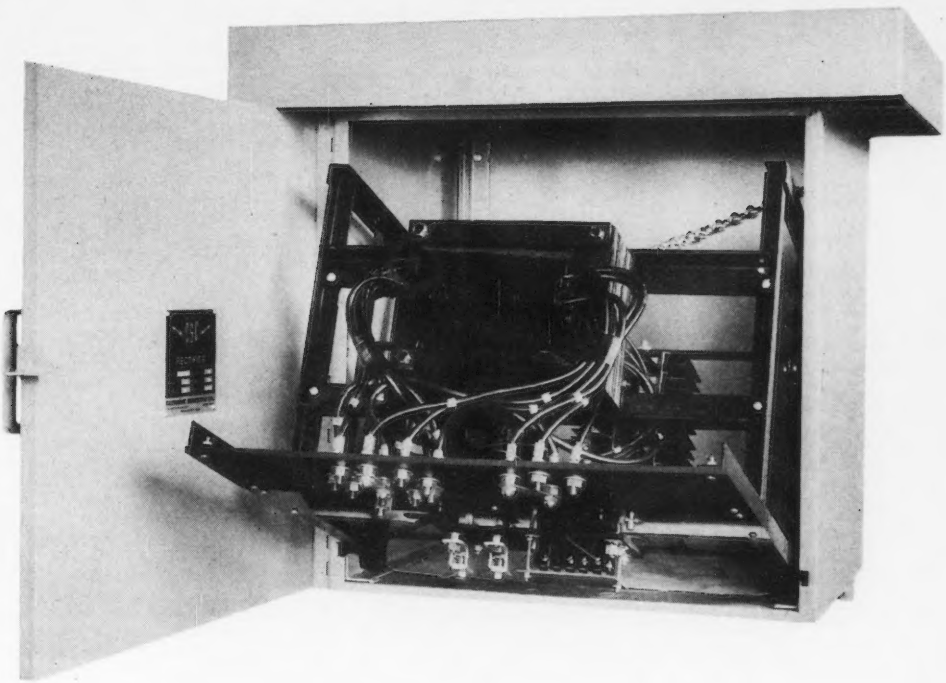
Firms producing corrosion mitigation materials or engaged in corrosion mitigation services are urged to send notices about new processes, materials or developments for consideration as items in the "New Products" section of CORROSION.

TIME IS MONEY



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OKLAHOMA CITY, OKLA.

Provisions for "Lighter Side" Include Show Tickets, Elaborate Program for Ladies

The Entertainment Committee headed by Linden Stuart, Jr., has been working to assure that the lighter side of the 1951 Conference and Exhibition will be as outstanding as the excellent Technical Program which has been arranged.

Linden Stuart, Jr.

The banquet to be held on Thursday evening, March 15, will feature a full-course dinner prepared by chefs of the Statler Hotel, noted in New York for the excellence of its cuisine. As a preliminary to the show to be given, the City of New York will extend official welcome and good wishes to the members of NACE. The show itself will feature several fast moving Broadway acts of stage, radio, and television—varied entertainment to suit every taste.

The Fellowship Hour to be held Tuesday evening, is sponsored by the exhibitors, but arrangements have been made by the Entertainment Committee to provide comfortable surroundings and service sufficient to meet the needs of the large group expected.

In cooperation with Mrs. Bailey's Ladies' Committee, there will be a really outstanding program of events available to the lady guests. These will include visits to radio and television studios, tea at the Rainbow Room high over Radio City, lunch and a fashion show in the famous Cotillion Room of the Hotel Pierre, and a visit to a large trans-Atlantic liner (ship schedules, security measures, etc., permitting).

With the assistance of the New York Convention and Visitors Bureau, Inc., tickets for theatre shows, sports events, etc. will be obtainable at standard rates. The Information Booth at the Conference will be the center of this activity.

Stuart and his committee members will be on hand to help the visitor to New York find entertainment of the type he wishes.

TP-16 to Hold First Meeting in New York

The first meeting of Technical Practices Committee 16—Electrolysis and Corrosion of Cable Sheaths will be held at 9 a.m. Monday, March 12, at Hotel Statler, New York City, it was announced by Irwin C. Dietze, chairman.

All members of the committee and non-members interested in its work are invited to attend. Membership and scope of the committee has been published separately and distributed to committee members of record February 1, 1951. Additional copies of the scope and membership may be secured on application to Mr. Dietze. Names and addresses of committee chairmen will be found in the Directory of Technical Practices Committees in this issue.

Theater Tickets Can Be Purchased in Advance

The Conference Entertainment Committee headed by Linden J. Stewart has mailed to each member of NACE a card on which reservations may be made in advance by those attending the 1951 Conference of theater tickets and admission tickets to other kinds of amusements.

No reservations for theater tickets will be taken except by mail in advance of the opening of the conference.

Questions for Round Tables Are Solicited

Questions to be answered at the 1951 NACE Conference in New York during the Round Tables on Pipe Line and Underground Corrosion and General Corrosion are being solicited by the chairmen of the discussions. Robert L. Bullock, Interstate Oil Pipe Line Company, P. O. Box 1349, Tulsa, Oklahoma, chairman of the Pipe Line Session, and F. L. LaQue of The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y., chairman of the General Corrosion Session, are soliciting questions for their respective round tables by mail from NACE members. Those who wish to do so may mail questions to be answered during the round table sessions to the appropriate chairman.

Mr. LaQue and Mr. Bullock will have present men qualified to answer the questions submitted by mail, or presented from the floor. Supplementary discussion from the floor will be welcome. The purpose of seeking questions by mail in advance of the programs is to guide the chairmen in making arrangements for people to be present who can answer the questions that have been submitted. These sessions provide an opportunity to air any questions or topics that are not touched upon in the formally scheduled papers.

The round table discussions at the St. Louis Conference in 1950, proved to be among the best attended and most interesting items on the technical program. There is every reason to believe the 1951 sessions will be equally, if not more interesting.

Mr. Bullock already has mailed a reply postcard to members seeking questions and Mr. LaQue is expected to make a similar mailing soon. Questions may be sent to either chairman by mail in any convenient manner and need not be sent on the reply cards unless it is desired to do so.

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Active and corporate members of NACE may obtain free classified advertising under Positions Wanted and Positions Available headings. Details may be found on Page 11 of the January, 1951 issue of CORROSION.

Procedure Is Outlined For Collection of Technical Discussions

Arrangements have been made for collection of discussions applicable to technical papers presented at the 1951 National Association of Corrosion Engineers' Annual Conference at Hotel Statler, New York City, March 13-16. Procedure will be essentially the same as that used at St. Louis in 1950. Changes that will be made are designed to get more discussions than in the past.

Essentials of the procedure are as follows:

1. Each person making a comment will be asked to fill in a discussion record form with his name, mailing address and a brief statement of the sense of his remarks, and the identifying number of the paper to which he referred.

2. He will be asked to deposit this form in one of the boxes which will be provided for the purpose in each room where the technical program is being held, and elsewhere.

3. A stenographer will be present at each technical session whose duty it will be to record the name and mailing address of each person making a comment, together with the identifying number of the paper to which the remarks refer. To facilitate this each speaker will be asked to state clearly his name and mailing address or company affiliation.

4. All records of discussions will be collected at Central Office, combined, and a written request for discussion in writing will be sent to each person whose name is of record. In no case will discussions be published unless they are submitted in writing by the discusser.

5. Written discussions will be collected and after a date to be determined later, all will be sent to the authors of the technical papers to which they refer for such replies or comments as the authors choose to make.

6. Discussions, plus authors' replies then go to Dr. Ivy M. Parker, Editor of CORROSION, who reviews them prior to publication. When possible discussions are published with the paper to which they refer. When papers have been published before discussions have been received and approved for publication, they will be published in succeeding issues as they become available.

7. Discussion Record forms will be available from symposia officials, and may be found inserted in the official conference program also.

8. Discussions prepared in advance of technical sessions for presentation at the symposia should be sent in duplicate to Central Office, NACE. It is not necessary to use forms provided to submit discussions, but it is very useful to have them submitted in duplicate.

9. Persons preparing written discussions for publication in CORROSION are urged to present all the information pertinent to the discussion as necessary, including illustrations, tables and other data. Discussions expanded beyond that presented during the limited time available following the presentation of technical papers are welcomed.

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Copies of most back issues of CORROSION are available for sale: To NACE members, 50c per copy; to non-members, 75c.

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TECHNICAL COMMITTEE REPORTS:

FIRST INTERIM REPORT ON GALVANIC ANODE TESTS *(Publication 50-2)* of Technical Practices Committee No. 2 "Galvanic Anodes for Cathodic Protection."
- Single copy postpaid to members of the Association 3.00
- To non-members of the Association 5.00

FIRST INTERIM REPORT ON GROUND ANODE TESTS *(Publication 50-1)* of Technical Practices Committee No. 3, "Anodes for Impressed Currents."
- Single copy postpaid to members of the Association 3.00
- To non-members of the Association 5.00

PUBLICATIONS:

JOINT SYMPOSIUM ON CATHODIC PROTECTION
- To members of the Electrochemical Society and the National Association of Corrosion Engineers, per copy .. 6.00
- To all others, per copy 8.00

BIBLIOGRAPHIC SURVEY OF CORROSION, 1945
- Single copy postpaid to members of the Association 4.00
- To non-members of the Association 5.00

PROCEEDNGS, FIRST ANNUAL MEETING, NACE
- Single copy postpaid to members of the Association 3.00
- To non-members of the Association 6.00

DIRECTORY, AMERICAN COORDINATING COMMITTEE ON CORROSION
- Single copy, postpaid 2.00

REPRINTS:

FIRST INTERIM REPORT ON RECOMMENDED PRACTICES FOR SURFACE PREPARATION OF STEEL *(Publication 50-5)* of Technical Practices Committee No. 6G "Surface Preparation for Organic Coatings."
- Less than ten copies, postpaid ..... Each $ .50
- Ten or more copies, postpaid ..... Each $ .25

CONTROL OF PIPE LINE CORROSION
by O. C. Mudd
- Single copy, postpaid $1.25
- (Five or more copies to a single address, postpaid at $1.00 per copy)

SELECTED BIBLIOGRAPHY ON SALT SPRAY TESTING
by Lorraine R. Voigt
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- Single copy, postpaid ..... $ .75

TO: NATIONAL ASSOCIATION OF CORROSION ENGINEERS, 919 Milam Bldg., Houston 2, Texas

Please send me the following publications:

- ☐ First Interim Report on Galvanic Anodes Tests (50-2)
- ☐ First Interim Report on Ground Anode Tests (50-1)
- ☐ Joint Symposium on Cathodic Protection
- ☐ Bibliographic Survey of Corrosion, 1945
- ☐ Proceedings, First Annual Meeting, NACE
- ☐ Directory, American Coordinating Committee on Corrosion
- ☐ First Interim Report on Recommended Practices for Surface Preparation of Steel (50-5)
- ☐ Control of Pipe Line Corrosion
- ☐ Selected Bibliography on Salt Spray Testing
- ☐ Corrosion in Condensate and High Pressure Sweet Oil Wells
- ☐ The Mitigation of Corrosion on City Gas Distribution Systems
- ☐ Causes of Corrosion in Airplanes and Methods of Prevention
- ☐ The Use of Ammonia in Control of Vapor Zone Corrosion of Storage Tanks
- ☐ CORROSION Magazine—Indicate month ( ) and year ( )

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NEWS ABOUT THE 1951 EXHIBIT – LARGEST HELD BY NACE

Most of Corrosion Mitigation Field Will Be Covered by Display

Following is a list of exhibitors and their booth numbers as of January 10, 1951 for the Seventh Annual NACE Conference and Exhibit, Hotel Statler, New York City, March 13-16, 1951:

Aluminum Company of America, Pittsburgh, Pa., 82, 83; Amercoat Corp., South Gate, Cal., 34; Anderson-Prichard Oil Corp., Oklahoma City, Okla., 57; Apex Smelting Co., Chicago, Ill., 79; Bakelite Division, Union Carbide & Carbon Corp., New York City, 90a, 91a; Barrett Division, Allied Chemical & Dye Corp., New York City, 31; Bart Manufacturing Co., Inc., Belleville, N. J., 7;

Polyken Industrial Tape Dept., Bauer & Black, Chicago, Ill., 53; Bridgeport Brass Co., Bridgeport, Conn., 42, 43, 44; Briggs Bituminous Composition Co., Philadelphia, Pa., 89; Cameron Iron Works, Houston, Texas, 77; Catodic Protection Service, Houston, Texas, 12; Cathodic Servicing Co., Oklahoma City, Okla., 51, 52;

M. J. Crose Manufacturing Co., Tulsa, Okla., 49; Crutcher-Rolfs-Cummings, Inc., Tulsa, Okla., 33; Dearborn Chemical Co., Chicago, Ill., 63, 64; The Debevoise Co., New York, N. Y., 21; Dow Chemical Co., Midland, Mich., 97; Dowell, Inc., Tulsa, Okla., 65, 66; Dresser Mfg. Div., Bradford, Pa., 13; Duriron Company, Inc., Dayton, Ohio, 95;

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National Association of Corrosion Engineers, Houston, Texas, 106; Natasco Co., Tulsa, Okla., 75; National Carbon Division, Union Carbide & Carbon Corp., New York City, 23; National Lead Co., New York City, 90, 91; Nelson Electric Manufacturing Co., Tulsa, Okla., 48; Nukem Products Corp., Buffalo, N. Y., 14; Oklahoma Glass Fiber Corp., Newport, Ark., 41; Owens-Corning Fiberglas Corp., Toledo, Ohio, 61, 62;

Permolite Inc., Hamilton, Ohio, 20; Perrault Bros., Inc., Tulsa, Okla., 22; Philip Carey Mfg. Co., Cincinnati, Ohio, 78; Pipe Line Service Corp., Franklin Park, Ill., 28; Pipe Protection Service, Inc., Elizabeth, N. J., 99; Pittsburgh Coke & Chemical Co., Pittsburgh, Pa., 46, 47; Plastic Engineering and Sales Corp., Fort Worth, Texas, 11; Prufcoat Laboratories, Inc., New York City, 81;

Refreshment booths, 93, 94; Reilly Tar & Chemical Corp., Tuckahoe, N. Y., 5; Royston Laboratories, Inc., Blawnox, Pa., 37; Rust-Oleum Corp., Evanston, Ill., 32; Service Engineers, Inc., Fort Worth, Texas, 39; Sola Catalytic Co., Dallas, Texas, 80; Somastic Pipe Coating, Bechtel Corp. & H. C. Price, Bartlesville, Okla., 76; South Florida Test Service, Miami, Fla., 40; Standard Pipeprotection, Inc., St. Louis, Mo., 84; D. E. Stearns, Co., Shreveport, La., 18, 19; Tapecoat Co., Evanston, Ill., 69; Tinker & Rasor, San Gabriel, Cal., 72; Tretolite Div., Petrolite Corp., Webster Grove, Mo., 35;

United Chromium, Inc., New York City, 30; U. S. Stoneware Co., Akron, Ohio, 102, 103; Westinghouse Electric Corp., Pittsburgh, Pa., 59, 60; Wilkinson Products Co., Los Angeles, Cal., 17; T. D. Williamson, Inc., Tulsa, Okla., 1, 2.

EXHIBIT FLOOR PLAN

A floor plan of the Exhibit area at Hotel Statler, New York was printed in CORROSION, November, 1950, Page 2, NACE News section. Since this plan was prepared there have been added two booths, 90a, and 91a, which are opposite booths 90 and 91 on the printed plan.

Information About Products and Services at New York Exhibit

BART MANUFACTURING CO., INC. Booth 7

The Bart Lectro-Clad Process will be shown. This process is one which electrolytically deposits a predetermined thickness of nickel on the inside and/or outside of pipe tubing, fittings, etc. It develops a smooth, ductile, pore-free nickel deposit fully adherent to the base metal which is corrosion and rust resistant and also prevents contamination.

Lectro-clad pipe can be welded, reduced or bent hot or cold without destroying internal plating. Pipe and tubing from two to 24 inches, in random lengths and approximately 20 feet long, plain ends can be processed together, with fitting and pipe line accessories. The coating makes possible piping installations free of horizontal and longitudinal seams, and increases the range of temperatures and pressures.

Pipe coated by the process are being used in many industries, including paint and varnish, petroleum, water works, plastic, coke and gas products and many others.

BRIGGS BITUMINOUS COMPOSITION CO. Booth 89

An entirely new product which can be sprayed over steel pipe, composed of ceramics and Farbertite, will be shown.

The combination material to be shown is effective against soil stresses. Constant experimentation is under way to develop improvements which increase the ability of the coating to prevent corrosion.

CAMERON IRON WORKS, INC. Booth 77

Cameron Non-Lubricated Lift-Plug Valves will be shown at the booth. The valve, which was shown at the St. Louis NACE meeting in 1950 has met with unusual acceptance in petroleum producing and refining and petrochemical industries. Cameron will show a 12-inch pipe line valve, produced with facilities added during the year.

The Non-Lubricated Lift-Plug Valve was developed in a 10-year period beginning in 1939, and several thousand have been installed since commercial production started in 1949. Features which make it an important advancement in design include the separate, replaceable seat, which not only simplifies service, but makes possible trimming of the valve with corrosion-resistant materials. The novel actuating mechanism assures effortless operation. Two company representatives will be present to explain the valves.

CATHODIC SERVICING CO. Booths 51, 52

Advance design cathodic protection equipment will be shown by Cathodic Servicing Company. On hand to display and explain the equipment will be Ted Riseling and Miles Carmichael. Latest designs in air cooled and oil immersed models of selenium rectifiers, Thermo-Galvanic generators and electrolysis switches will be displayed.

The Thermo-Electric Generator was developed for use in areas were electric current is not readily available for cathodic protection installations. The generator, by burning a small amount of gas from gas transmission lines, produces 50 watts of continuous DC current in

(Continued on Page 34)

COMPARE

YOUR PRESENT

PIPE LINE
WRAPPING MATERIAL

WITH

GAMA ASBESTOS PIPE LINE FELT

How does your present wrapping material answer these questions?

QUESTION:	YOUR PRESENT MATERIAL:	GAMA ASBESTOS PIPE LINE FELT:
Of what material is it made?		High quality Canadian chrysotile asbestos fibers.
How long has this type material been in use?		For almost 30 years.
Is data covering long time testing of this material available?		Yes, by the American Gas Assn., the National Bureau of Standards, and the A.P.I. tests in 1930.
Is it a positive shield against soil stress?		Yes. It is at the outside, partially imbedded, and at the point where needed.
Does it reinforce the enamel?		Yes. Its strong fibers lend needed reinforcement.
Does it tighten coating to the pipe?		Yes. It is a strong, thick sheath of asbestos in solid roll lengths.
Is it moisture resistant?		Yes. Tar saturant is moisture resistant. Asbestos fibers are solid, not tubular or hollow.
Does it have high fiber count?		Yes. A natural characteristic.
Is it uniform?		Yes.
Does it have high impact resistance?		Yes.
Does it apply easily and evenly?		Yes. Accurate make-up gives precision laps.
Does it prevent backfill damage?		Yes.
Does it prevent lowering-in damage?		Yes.
Does it give an even thickness of enamel on top, bottom and side of pipe?		Yes.
Is it a protection for the coating beneath it?		Yes. It stops damage at the outside—before it starts.
Does it prevent damage from abrasive movement coating receives in shipping or handling?		Yes.
Does it stick in the rolls?		No.
Does it have high tensile strength?		Yes. Lengthwise—44 to 52 lbs.; Sidewise—15 to 21 lbs.
Does it relieve gas bubbles?		Yes. By compressing action.
Is it chemically resistant?		Yes. Both asbestos and tar are very inert to most corrosive forces.
Can holiday detectors be run freely over its surface?		Yes.
Can it take rough, abusive handling?		Yes.
Does it irritate workmen?		No.
Is it a foreign material in the enamel?		No.

Manufactured By

GAMA INDUSTRIES, INC.

70 Pine Street New York 5, N. Y.

Distributed By

MIDDLE WEST COATING & SUPPLY

207-A Daniel Bldg. Tulsa, Okla. Ph: 2-5215

Information About Products and Services at New York Exhibit

(Continued from Page 32)

various voltage and amperage combinations which can be changed by simple tap adjustments.

The electrolysis switch was designed to control stray currents prevalent on pipe lines or other structures adjacent to electric railway systems. The switch is designed to return stray currents from the buried structures to the negative return of the railway system, and when reversals occur, will block these reversals up to 200 volts. Rated forward drainage of the switch is 500 amperes continuous load, but surges up to 2500 amperes can be handled. The switch uses an electronic bridge circuit with adjustable closing values of 50 to 250 millivolts and adjusting opening values of 0 to 50 millivolts.

CRUTCHER-ROLFS-CUMMINGS, INC.
Booth 33

A diorama built by E. M. Wallace of Tulsa, Okla., one of the leading artists in the United States will depict a pipe line "spread" showing the various lines of equipment handled by Crutcher-Rolfs-Cummings, Inc. Mr. Wallace and his assistants spent considerable time in the field with color cameras and sketch pads to get enough information to create the display. Eleven months were occupied in constructing the diorama. A better idea is gained of the details of pipe line installation from an inspection of the diorama than an equivalent time spent on an actual job, because all operations are shown. E. L. Rolfs and Bo Bardsley will represent their company at the booth.

DEBEVOISE COMPANY, THE
Booth 21

An extensive presentation of Debevoise special anti-corrosive coatings and paints will be shown, especially featuring Debcote, a coating for use in surface condensers, pumps and other applications where the metal surface is subject to damage from erosion or pitting from water turbulence.

Other products to be shown, about which technical information will be available are: Dereka Metal Paints, designed principally for use as primers to provide maximum protection; Debevoise Miracle Red No. 554, a coating which is both a rust-inhibitive primer and complete protection against moisture and severe fumes; Drumcote, a special coating for internal surfaces of boiler drums, hot water tanks, heaters, etc.; Debevoise Heat Resisting Gray No. 3182, for breechings, boiler casings indoors and out; Aluminum paints, several types designed for protection against severe conditions.

DOWELL INCORPORATED
Booths 65 and 66

Magnesium anodes, including several new sizes and forms for internal protection of turbocondensers and other heat exchange equipment, marine vessels and utility distribution systems and other special applications, will be shown. Also to be displayed will be Saran rubber tank lining, developed by The Dow Chemical Company. Saran combines desirable features of rubber, flexibility, strength, with exceptional resistance to abrasion and corrosive liquors. It has applications in many industries including petrochemical and chemical where corrosion by strong solutions or damage from abrasion is a problem. Saran lining can be installed without vulcanizing equipment.

DURIRON COMPANY, INC.
Booth 95

Corrosion resistant alloys and equipment will be featured again by The Duriron Company at its 1951 exhibit. Included will be new and thoroughly proved Teflon-lined plug valve which was introduced first at the 1950 NACE Exhibition. Wide acceptance of this novel valve warrants its inclusion in the display. Durco "Y" valves, with many new and interesting features and conventional plug valves will be shown. A Durco centrifugal pump will be displayed. Of the recently released Series R design, with many desirable features, it will be made from Duriron, Durichlor, Durimet 20 and Chlorimet as well as other corrosion resistant alloys. Staffing the exhibit will be Duriron engineers who specialize in handling corrosion problems. Descriptive bulletins will be available also.

FEDERATED METALS DIVISION, American Smelting & Refining Co.
Booth 58

A full range of sizes and types of magnesium anodes for cathodic protection will be exhibited by Federated Metals Division. Made in all standard sizes and shapes, they have the exclusive long electrogalvanized spiralwound strip core which is bonded completely to the metal, assuring perfect electrical contact essential to good performance.

Special shapes also will be shown, such as one developed for use in oil tankers. This 36 x 4 inch anode with square cross section, weighs about 45 pounds. It has an integrally cast magnesium bracket to space the anode 10 inches from the tanker bulkhead. These anodes are used to protect tanker plates when sea water is carried as ballast. A five pound anode with packaged backfill ready for field installation, particularly designed for protection of main-to-meter gas service lines, also will be shown.

GENERAL ELECTRIC COMPANY
Booth 50

Laboratory products for chemical analysis will be featured at the General Electric booth. GE's electron diffraction instrument will be shown also, and a table of photographs of work samples. A new small selenium rectifier also will be displayed.

HILL, HUBBELL & CO. DIV., General Paint Corp.
Booths 104-105

Modern methods used by Hill, Hubbell & Company Division of General Paint Corp., at its Lorain and Girard, Ohio, plants will be the keynote of the firms' display. A large sample of pipe Roto-Grit-Blast cleaned and wrapped, then peeled to expose all coatings, will be shown. It will help engineers visualize Hill, Hubbell's pipe protection process.

A new feature will be the complete story of the Roto-Grid-Blast angular steel grit blasting processing used by the company as an extra measure to assure positive permanent bond of coating and wrapping. Samples of pipe before and after grit-blasting will be given away. Enlarged photographs show the six steps in the company's process. Several of Hill, Hubbell's engineers will be at the booth as will be Milt Bowen, vice-president and division manager of Hill, Hubbell and Co.

HEIL PROCESS EQUIPMENT CORP.
Booth 98

Facilities for the fabrication of impervious graphite heating and cooling units will be highlighted at Heil Process Equipment Corporation's booth. Portions of the standard line of units will be displayed. Also to be shown will be acid-proof linings such as Neoprene type rubber, Heilex No. 445, and lead. Small display tanks will be shown to point out facilities for lining process equipment with Neoprene and samples of acid resistant materials that can be applied by plant personnel will be shown.

HILLS-McCANNA COMPANY
Booth 56

Hills-McCanna, pioneers in the development of the Saunders valve, will show two diaphragm developments: The L-1 plastic diaphragm which will handle 66 degree Baume sulfuric acid at temperatures under 1250 degrees F and pressures below 100 psi, and (the result of constant experimentation)—as good a plasticized Kel-F diaphragm as present "know-how" makes possible. The latter development is offered on an experimental basis only.

Of interest to pipe line and oil companies will be Hills-McCanna hydraulic drive "K" pumps and the Model "U" pump. The former offers virtually maintenance free linear operation at pressures up to 30,000 psi, capacities of 200 gph per feed, with or without electrical positioning, and the latter offers a conventional rack and pinion, lost motion design at reasonable cost for pressures up to 4800 psi and capacities around 70 gph.

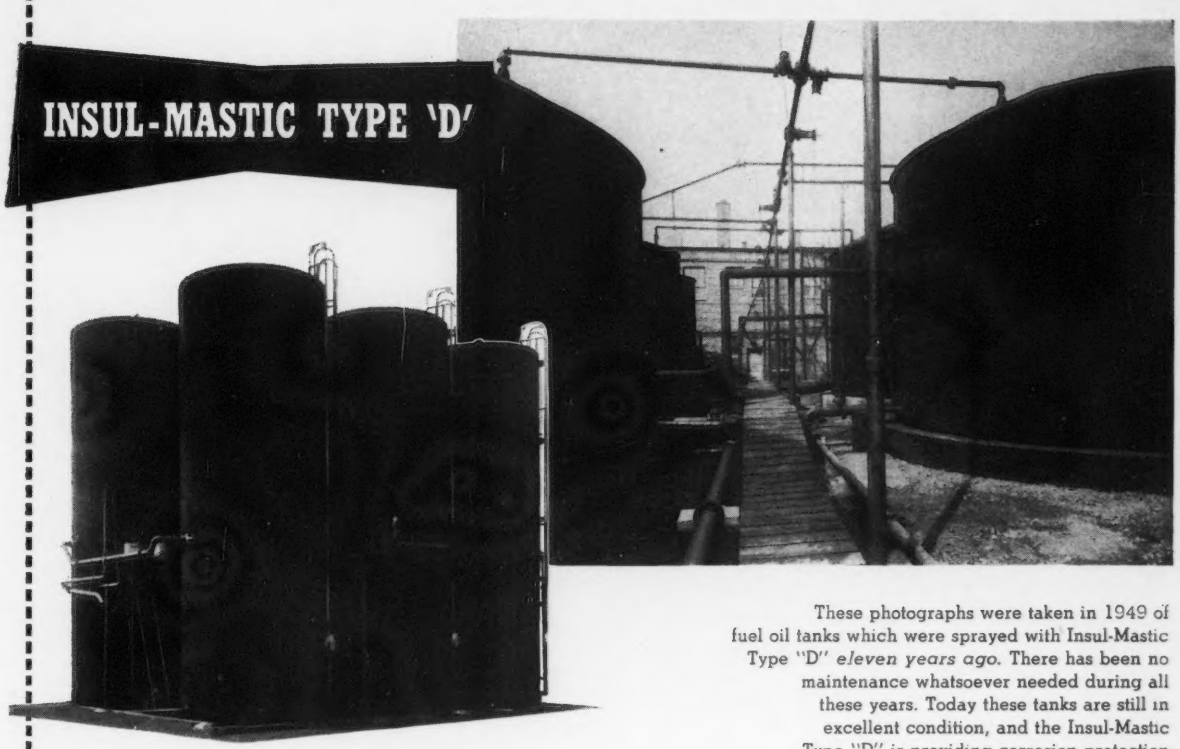
INSUL-MASTIC CORPORATION OF AMERICA
Booths 85, 86

Gilsonite protective coatings which have gained such prominence in industry since selection by the government a few years ago as the vaporseal used in "wrapping" huge bombers for storage, will be shown. Coated panels for tests suspended in acid tanks and other corrosive atmospheres are often supplied by the company. Insul-Mastic Protective coatings have a temperature range from minus 40 degrees F to 300 degrees F, with no cracking or slipping in the range.

Also to be shown is Insul-Mastic Type D, an unusual coating which not only is a corrosive preventive but also an insulation. It is a Gilsonite-based coating to which has been added a large proportion of granulated cork, useful in insulating and corrosion-proofing tanks,

(Continued on Page 36)

The coating that both insulates and prevents corrosion



These photographs were taken in 1949 of fuel oil tanks which were sprayed with Insul-Mastic Type "D" *eleven years ago.* There has been no maintenance whatsoever needed during all these years. Today these tanks are still in excellent condition, and the Insul-Mastic Type "D" is providing corrosion protection and unimpaired insulating value.

Serves many years without maintenance

INSUL-MASTIC TYPE "D" is the dual purpose coating that not only insulates but also prevents corrosion. It is quickly applied to tanks, ducts, pipes and other metal vessels by spray gun and adheres at any angle without mechanical support.

INSUL-MASTIC TYPE "D" will stop heat flow through metal by 65%, and pays for itself in a short time by fuel saving—such as in the case of oil storage tanks, where heat is used to maintain a free flowing viscosity.

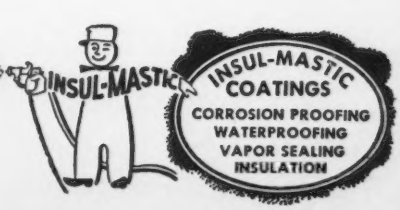
INSUL-MASTIC TYPE "D" also prevents condensation and has proven to be very effective on cold water intake lines in power houses and other places where water absorbent insulations have given trouble.

INSUL-MASTIC TYPE "D" consists of granulated cork thoroughly mixed into a Gilsonite base binder, hence its corrosion preventive and adhesive properties. It is also resistant to most acids and alkalis.

INSUL-MASTIC TYPE "D" is effective between -40° to +300° F. Beyond these extremes, use the Insul-Mastic Vinyl System. Our nearest representative will gladly help you.

Write for further information or see our catalog in Sweet's Process Industries.

Insul-Mastic Corporation
OF AMERICA
1164 OLIVER BUILDING · PITTSBURGH 22, PA.
Representatives in Principal Cities



Information About Products and Services at New York Exhibit

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ducts and other vessels with one application and at one cost.

LEBANON STEEL FOUNDRY
Booths 70, 71

Lebanon's Circle L-12 pressure castings (12 percent Cr.) to be exhibited, have high strength characteristics plus corrosion resistance which has extended the use of this type of casting to many new applications. Many of the cast industrial parts display engineering designs that have been planned carefully and manufactured under controlled operating methods. These methods include Centri-Die (Permanent Mold Centrifugal Castings), special refractory molds, and static castings to meet exacting requirements for corrosion resistant applications. The Lebanon foundry produces high strength pressure parts, such as Christmas-tree fittings for condensate gas wells, and is working closely with producer and consumer to develop new materials and designs to cope with ever-increasing temperatures, velocitis, pressures and corrosive conditions.

METALLIZING ENGINEERING CO., INC.
Booth 74

Workings of a modern metal spraying installation, samples of proved metallizing applications for corrosion protection and descriptions of a new technique for the protection of iron and steel will be featured by Metallizing Engineeering Co. A four-page bulletin describing Metco systems, their uses and applications, will be available. The system affords a sacrificial coating of pure zinc or aluminum, plus added protection from organic seal coatings firmly keyed to the zinc or aluminum. When the weathered seal coating exposes the anodic zinc or aluminum coatings, further protection is afforded by the metallized coatings. Case histories of corrosion elimination for 20 years will be available, including steel bridges, ship hulls, water tanks and others. A company representative will be on hand to discuss corrosion problems.

NATASCO COMPANY
Booth 75

Cutaway miniature tanks showing typical corrosion problems and their control through use of Natasco products and services will be shown. Panels showing many of the company's corrosion prevention products will be displayed, where their properties may be examined.

A new product which is finding a wide market where liquids are stored in tanks also will be shown. This is the Natasco Liquid Level (Remote Reading) Gauge. With this equipment any number of tanks at widely separated points may be gauged instantly and accurately, from any central point. Walking from tank to tank, climbing and pole and line gauging are eliminated. J. C. Nicholson, vice-president of Natasco, will be in charge of the exhibit.

NATIONAL LEAD COMPANY
Booths 90, 91

Modern types of protective red lead paint coatings and modern applications of metallic lead in lead-lined equipment will be featured by National Lead Company. Examples of protection afforded by proper formulation or red lead paints and paint systems for different corrosive environments, marine and atmospheric, will be shown. An "on the spot" demonstration of "Nalco" metal in Chromium plating solutions will be of interest to engineers in the plating industry. As historic background a section of 1900-year-old Roman water pipe will be on view again.

For discussion of corrosion problems the following technical men will be available during the exhibit: For protective coatings, George Diehlman, Ralph Baker and Norman Webb; for the metal department of the research laboratories, Carl Hack, George Hiers and D. L. Hawke, and from the New York office of the company, Henry Freiherr, A. Podesta and J. H. Sabo.

NELSON ELECTRIC MFG. CO.
Booth 48

The Nelson Electric Manufacturing Company's well-known line of "Nemco" selenium rectifiers for cathodic protection; Nemco insulating materials for pipe nipples and the insulation of pipe line flanges, pipe line locators, the new and improved Pearson Electric Coating Inspector, portable electronic voltmeter, Shepard Soil Resistance Meter, copper sulfate electrodes and other test equipment will be displayed. H. A. Norberg, manager will be company representative at the booth.

NUKEM PRODUCTS CORP.
Booth 14

With its complete showing of acid proof cements and coatings, Nukem will present a working model of the Nu-Kast pump. Introduced to the plating and steel industry in 1949, the pump has no metallic parts exposed to corrosive solutions. The pump is built of carbonaceous resins with outstanding corrosion resistance properties and has a simple design. Four compression rings in the pump seal eliminate the stuffing box and the necessity for pump seal lubrication, irrigation or external cooling devices. Available in ½-horsepower and two horsepower sizes, either close-couple mounted on totally enclosed motors or on pulley drives for separate connection, they have all exposed metal surfaces sprayed with an acid-proof resin coating for long service under severe operating conditions.

The Nukem-Karbate heat exchanger, which also utilizes the resistance of non-metallic materials, will be connected to a Nu-Kast pump in the display. A transparent tubing intake pipe will show the rapid flow of liquid.

PLASTIC ENGINEERING & SALES CORP.
Booth 11

The Pesco Tapester 5, developed to apply plastic tape as a pipe coating, will be displayed and in operation. The simplicity, portability and flexibility of the machine will be demonstrated by coating several sizes of pipe, including screwed couplings and field joints of central yard coated pipe. Also to be demonstrated will be the ease with which Polyken Tape may be applied by hand. The Pesco Insulating Coupling for screw pipe and the Pesco Seal Ring Gasket for ring joint flanges will be on display. Bob Cole and Leonard Daniels will be company representatives at the exhibit.

H. C. PRICE CO. & BECHTEL CORP.
Booth 76

H. C. Price Company and Bechtel Corporation as manufacturers and distributors of Somastic pipe coating will have the following company representatives at their booth: J. S. Dewar, E. R. English and R. P. White of H. C. Price Co. and J. S. Connell and Austin S. Joy of Bechtel Corp. These representatives will be prepared to discuss corrosion problems with visitors and explain the use and advantages of Somastic for severely corrosive locations, in swamps, areas with high water table and water crossings.

PRUFCOAT LABORATORIES, INC.
Booth 81

The Prufcoat line of maintenance coatings for masonry, metal and wood surfaces will be featured. Experience gained as pioneers in the formulation of special synthetic resin coatings for protection against acids, alkalis, alcohol, oil, salt and water has enabled the company to supply many leading chemical plants with corrosion protective materials, including some which manufacture mineral acids, organic acids and alkalis.

Norman E. MacCuspie, who in addition to being president of Prufcote, also is the chemist responsible for the development of its formulations, will be in attendance at the exhibit, with G. Russell Hersam, general sales manager, and Robert Hilton, assistant sales manager. Mr. Hersam, recently named Prufcoat sales manager will be remembered as one of the group which developed the "cocooning" process used for laying up the fleet. The new Prufcoat Metal-Reactice Primer P-10, which makes possible a simple but positive two-step system for corrosion proofing old or moist steel surfaces also will be shown.

SOUTH FLORIDA TEST SERVICE
Booth 40

Large, hand colored photographs of exposure facilities, test samples on exposure at South Florida Test Service's inland, salt atmospheric, tidewater and total immersion bases and instrumentation for measuring and recording all climatic data directly at inland proving grounds will be shown. A continuous showing of color slides detailing all phases of service will be featured.

UNITED CHROMIUM, INC.
Booth 30

Corrosion-resistant coatings with organic and metallic bases will be featured. Among the outstanding new products are Unichrome Plastisol Compounds which have rubber-like flexibility, are 100 percent solids, vinyl-base and may be applied by spraying or dipping. Thickness of .002-inch to 3/16-inch with a single application may be obtained. After baking the compounds exhibit resistance properties markedly superior to those of vinyl solution coatings because: 1) of

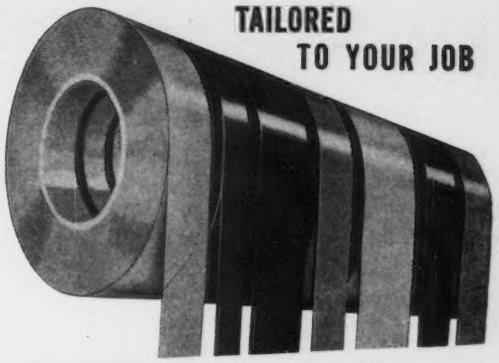
(Continued on Page 38)

THE NEW

Polyken®

INDUSTRIAL TAPES

TAILORED TO YOUR JOB



Now wrap buried pipe only once—for good! This buried pipe is hand-wrapped in a few seconds with *Polyken* No. 882. The polyethylene tape is especially oriented to s-t-r-e-t-c-h. Provides a lasting compression against the pipe. Sticks tight to irregular surfaces. And it's *permanent!*

The first permanent anti-corrosion coating for pipes

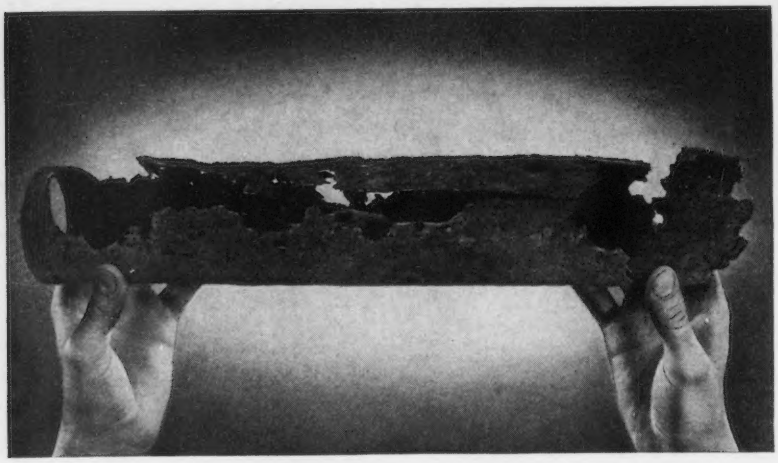
Now you can protect pipes against corrosion for good . . . *in* minutes! No need for heat, flame, solvents, or greases. Just wrap this new plastic tape (polyethylene) around pipes once and forget about corrosion. Resists moisture, soil bacteria, solvents, and has a dielectric strength of over 10,000 volts.

Use jet black *Polyken* No. 882 for underground installations—aluminum-colored *Polyken* No. 888 on above-surface pipe lines. For coating underground pipe, corrosive hot spots, above-ground installations on cooling towers, evaporators and piping exposed to corrosive atmosphere . . . these *Polyken* tapes save time, money, and *—pipe!* See your *Polyken* distributor.

FREE SAMPLES. Write now for free engineering and application data, plus samples, of *Polyken* Nos. 882 and 888. Address *Polyken*, Dept. CB, 222 West Adams St., Chicago 6, Illinois.

See us in Booth 53—Natl. Assn. of Corrosion Engineers 1951 Exhibition

Polyken Industrial Tape, Department of Bauer & Black, Division of The Kendall Company



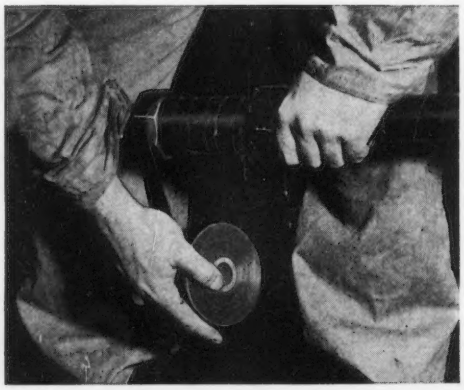
Stop corrosion with TAPE!

EARTH ACIDS, ALKALIES CAN'T HARM PIPES WRAPPED WITH PLASTIC TAPE

Industry pays two hundred million dollars each year to replace buried pipes that are rusted beyond repair! "SCOTCH" Electrical Tape No. 22 can cut *your* share of these corrosion costs.

This easy-to-apply tape is ideal protection against corrosion of pipes above or below ground. Its plastic backing has excellent resistance to corrosive action of soils, salt water, acids, alkalies and alcohols.

Clean, too! "SCOTCH" Electrical Tape No. 22 is quick to apply, sticks at a touch, eliminates the dangers of hot coatings. Estimated cost is *less than half* that of other coating methods! Write Dept. CO-251 for complete information.



NEAT, TIGHT WRAP with "SCOTCH" Electrical Tape No. 22 gives this gas service pipe thorough anti-corrosion protection.

QUICK FACTS ABOUT "SCOTCH" ELECTRICAL TAPE NO. 22

- **TOUGH**—plastic backing is unaffected by oil, water, acids, corrosive vapors, weather.
- **STRETCHY** — conforms snugly to irregular surfaces.
- **HIGH DIELECTRIC**—over 10,000 volts.
- **THIN CALIPER** — only .010 inch thick, gives neat jobs.
- **NON-CORROSIVE**—contains no sulphur-bearing compounds.
- **WIDTHS**—½ in., ¾ in., 1 in., 2 in., 3 in., 4 in.

The term "Scotch" and the plaid design are registered trade-marks for the more than 100 adhesive tapes made in U.S.A. by MINNESOTA MINING & MFG. CO., St. Paul 6, Minn. — also makers of "Scotch" Sound Recording Tape, "Underseal" Rubberized Coating, "Scotchlite" Reflective Sheeting, "Safety-Walk" Non-Slip Surfacing, "3M" Abrasives, "3M" Adhesives. General Export: Durex Abrasives Corp., New Rochelle, N. Y. In Canada: Canadian Durex Abrasives Ltd. Brantford, Ontario.

Information About Products at Exhibit

(Continued from Page 36)

the 100 percent solids composition and 2) the greater thicknesses obtainable. They are resistant to acids, alkalis, salt solutions, water, oxidants and other corrosives.

The whole line of Ucilon protective coatings will be shown, including display pieces protected with special vinyl, phenolic, chlorinated rubber, fish oil and water emulsion systems. A new Ucilon coating of interest is an air-drying phenolic type with excellent resistance to acids, aliphatic hydrocarbons and moderately high temperatures. Another important development to be seen is Unichrome Primer AP-10, especially formulated for use on light metals. This primer, top-coated with suitable chemical resisting coatings, is expected to extend the use of light metals, and already has been highly praised by large producers and fabricators of aluminum and magnesium for its superior adhesion.

In the display of metallic-base coatings, zinc parts which have been passivated with the chemical Unichrome Dip Processes will be shown. These processes can produce clear, black and yellow coatings which increase manyfold the resistance of zinc to corrosion.

Committee Meetings to Precede Conference

Numerous meetings of standing and technical committees of the National Association of Corrosion Engineers will be held on March 11 and 12, the Sunday and Monday preceding the official opening of the 1951 NACE Conference and Exhibition at Hotel Statler, New York City. The association's board of directors usually meets on the Sunday preceding the opening of the conference, and on Monday numerous meetings of technical committees are scheduled.

Although it is impossible to give a schedule of meetings of technical committees so far in advance of the opening of the conference, some committees already have set times and dates. Insufficient time is available Monday for all committees to meet, however, and it is expected some will hold their conferences later in the week.

Times and dates of committee meetings will be posted at a place near the registration desk and probably in other parts of the hotel. Those interested in attending committee meetings are urged to seek the notices on the bulletin boards.

The annual meeting of the Inter-Society Corrosion Committee, which is sponsored by NACE, also is held during the conference. Time for this meeting will be announced by the chairman.

NACE to Have Booth

The National Association of Corrosion Engineers for the first time will have a formal exhibit at Booth 106 at Hotel Statler, New York during the 1951 Conference March 13-16. Panels will display specimens of badly corroded metal together with brief descriptions of the materials and corrosive conditions. The specimens are being supplied by NACE members throughout the nation.

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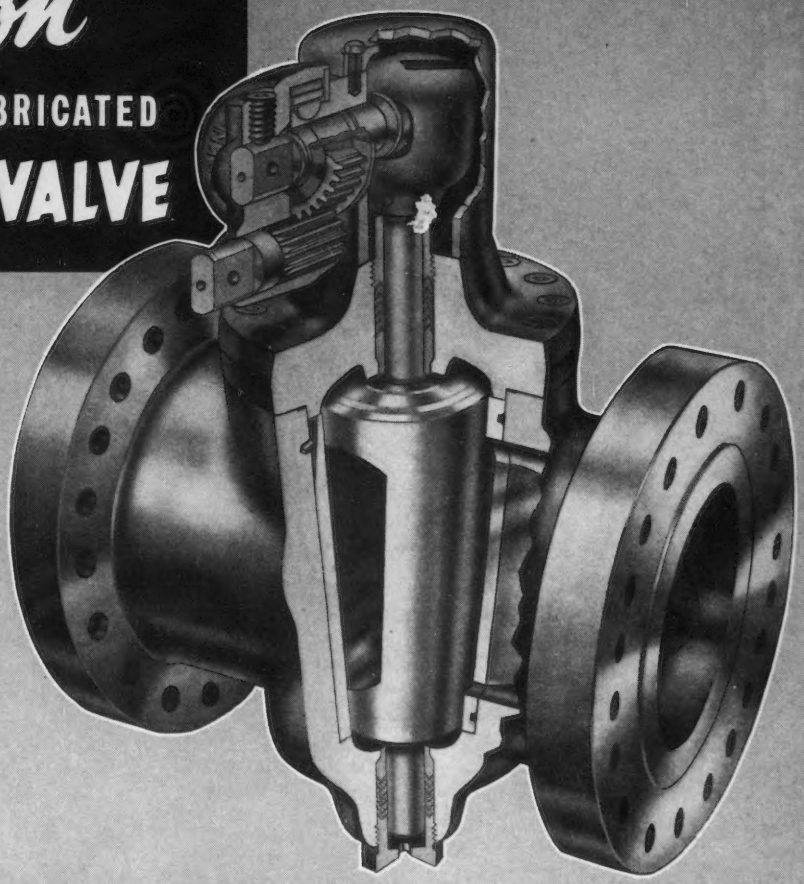

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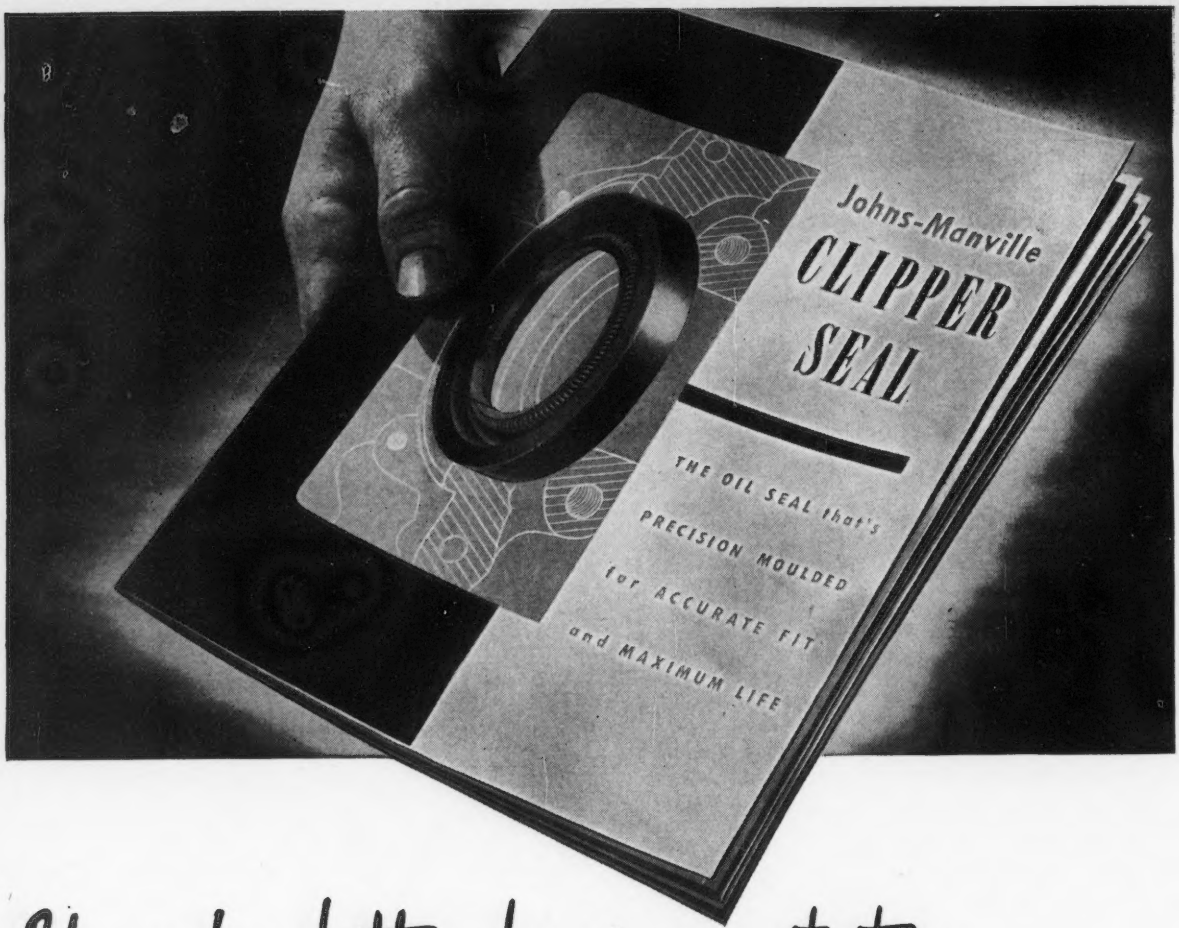

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CORROSION CONTROL — PROTECTIVE INDUSTRY — NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Corrosion Abstracts

Index to

CORROSION ABSTRACTS*

February, 1951

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   5. Factors Physical and Mechanical ... 31a
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5. PREVENTIVE MEASURES
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*** PAGINATION OF CORROSION ABSTRACTS**

Two numbers appear on each page of Corrosion Abstracts. The number in the upper outer corner is for page sequence within the issue only. The number in the lower outer corner, which is followed by the letter "a," denoting "abstracts," is for the convenience of those who bind Corrosion Abstracts by volumes. Because both numbers appear on each page and because it is believed indexing by the volume serial number will be more useful, effective with this issue the "Index to Corrosion Abstracts" will be keyed to the number found in the lower outer corner of each page followed by the letter "a."

TESTING

• Laboratory Methods and Tests

2.3, 1.8

Recent Experiments on the Local Galvanic Action of Oxide Coatings on Metal Surfaces. (In German.) F. Todt. *Archiv fur Metallkunde*, **3**, 273-278 (1949) Aug.

Above was studied by amplifying the rate of solution of "aerated" iron and by directly measuring the generated current of "aerated" metal surfaces (iron, copper, platinum) against a less noble and practically unpolarizable electrode. The two methods which supplement and confirm each other, afford an insight into the local galvanic action between metal and oxide skin. Rates of oxidation and thickness of oxide skins were determined and rules governing the dissolution of different metals (especially of aluminum) are explained. Includes tables. 19 ref.—BLR.

CORROSION TYPES AND INFLUENCING FACTORS

• Factors Physical and Mechanical

3.5

Corrosion (A Realistic Corrosion Research Program). Mars G. Fontana. *Indust. and Eng. Chem.*, **41**, No. 7, 63A-64A (1949).

A brief article dealing with a research program on corrosion by liquids at elevated temp.—MA.

PREVENTIVE MEASURES

• Non-Metallic Coatings and Paints

5.4

Improved Corrosion Inhibiting Pigment. M. L. Kastens and M. J. Prigotsky. *Die Castings*, **8**, No. 2, 44-49 (1950) Feb.

Barium potassium chromate pigment is used in the formulation of improved primers for the light metal alloys, Al and Mg. The protective effect is better on Al and Mg than on the ferrous metals. 20-25% more chromate ion per unit weight is added to enhance the anticorrosive action of the paint. Although it is a true double salt it hydrolyzes to release only potassium chromate and the barium chromate remains as a coating. The metals Ba and K do not promote polymerization of the vehicle oils catalytically, and the new pigment has a low tinting strength so it may be included in finish coats.—INCO.

5.4, 3.3

Anti-Fouling Paints (Role of Pigment Particle Size in the Performance of Toxic Paints). Allen L. Alexander, J. B. Ballentine, and M. O. Yeiter. *Ind. and Eng. Chem.*, **41**, No. 8, 1737-1741 (1949).

Standard pigment samples classified into fractions of measured particle size were incorporated into a standard antifouling matrix and two slightly varied vehicles, and examined in an attempt to establish the precise effect of particle size on performance. Only initial leaching-rate values appear to be enhanced by predominantly small particles of toxic pigment, the steady-state leaching rate remaining unaffected in a given matrix, regardless of particle size. In anti-fouling paints prepared from rosin and its derivatives larger pigments seem to reinforce the physical stability of the film much more effectively than extremely small particles; when, however, organic toughners are added for the purpose of strengthening the film, the influence of pigment particle size becomes less significant as a stabilizer of film integrity. —MA.

5.4

Transparent Liquid Coating Protects from Moisture, Acid. *Am. Machinist*, **92**, No. 11, 154 (1948) May 20.

Permacote, a transparent liquid skin for protection from corrosion, can be applied by brush, spray or dip. Mfd. by State Chem. Corp.—INCO.

5.4, 1.7

A Study of Primers for Ferrous Metals in an Atmospheric Exposure—Fifth Report. *Amer. Paint J. Convention Daily.* **34**, No. 6-C, 14-28 (1949) Nov. 3.

A report on the progress of the extensive primer tests being carried out by the New England Paint and Varnish Production Club. A table shows the assessment ratings of the test panels and angles after 16, 22 and 28 months. So few of the speciments have yet shown any failure at all that no conclusions can be drawn.—ZDA.

5.4

Is It Possible to Calculate the Life of Anti-Corrosion Paints by Investigation of Their Thin Films? (In French.) J. F. Bogtstra. *Metaux & Corrosion*, **25**, 147-162 (1949) June.

The relationship between thickness of the paint film and protective ability was investigated. Results indicate possibility of approximate calculation of the above by use of coefficients for paint composition and corroding medium. Error is up to 20-25%.—BLR.

5.4, 1.3

A Literature Survey of the Weathering Properties of Paints Containing Zinc Oxide. K. R. Russell. *Paint Notes* (Australia), **4**, Nos. 7-8, 217-24 (1949) July-Aug.

The author's review of literature having shown that differences in weathering properties were frequently connected with variations in particle size and shape, he began by considering definitions of these terms. As regards the fluorescence of zinc oxide in ultra-violet light, later workers disagree with earlier papers relating this effect to the purity and particle size of the pigment. Several authors state that acicular zinc oxide is more durable than the amorphous variety; but except in the case of the work by Kekwick and Pass, the present author does not feel that the experimental evidence justifies the conclusions reached concerning the reasons for this superiority. The author was unable to find any references in the literature to the early chalking of zinc oxide itself.—ZDA.

5.4, 6.4

Priming Coat for Light Metals. G. C. Close. *Light Metal Age*, **7**, Nos. 5/6, 6-8 (1949) Dec.

Northrup Seal Primer No. 75 is nothing more than ordinary zinc chromate primer fortified with a synthetic resin

that increases its protective qualities. Long range tests proved that the new seal primer retains all advantages of conventional zinc chromate with added advantages of being less porous and far more resistant to moisture penetration. Description of the tests is given in detail.—INCO.

5.4, 6.4

Tests on Some Special-Base Paints for the Protection of Magnesium Alloys. H. G. Cole. Selected (Brit.) Govt. Research Rep., Vol. II.—Paints, Rep. **1949,** No. 5, 35-48.

One or more of the following materials a) magnesium alloy sheet to D.T.D. 118, b) magnesium alloy sheet to D.T.D. 120A, and c) magnesium alloy castings to D.T.D. 281, were treated with the following paints: i) a proprietary black paint based on chlorinated rubber, stoved for ½ hr. at 80°C, and used without a chromate primer; ii) a proprietary air-drying primer and finishing coat; iii) undercoats pigmented with zinc chromate and based on vinyl chloride, vinyl, acetate, butyl and cellosolve methacrylates, and distrene; iv) a special primer for magnesium alloys pigmented with a mixture of zinc chromate and red oxide of iron. Sea-water spray corrosion tests were carried out on the paint coatings. It is shown that the proprietary black paint i) gave good protection, that the proprietary air-drying system ii) gave poor protection, though either paint used separately with a good-quality primer or finishing paint, as appropriate, gave good protection, and that a series of primers based on the substances mentioned under c) and pigmented with china clay and zinc chromate gave excellent protection with the exception of those based on distrene, which gave only fair protection. The dry films of these primers were soft and wrinkled, and they are thus not suitable for general use without modification.—MA.

5.4, 3.5, 5.9, 6.4

The Effect of Heating on the Corrosion-Resistance of Chromate-Treated and Painted Magnesium Alloy Castings. H. G. Cole. Selected (Brit.) Govt. Research Rep. Vol. II.—Paints, Rep. **1949,** No. 7, 53-62.

Magnesium alloy castings to D.T.D. 136A, 281, and 285 were used in this work and were chromated in baths i), ii), and iii) of D.T.D. 911. Some of the chromate-treated materials were painted with an undercoat and finishing coat, both known to be suitable for use on magnesium alloys. The paints were air-drying. Some of the specimens were heated to 160° C for 1 hr. Corrosion tests were carried out in a sea-water spray. It is shown that the heating reduces the protection given by chromate treatment to unpainted blocks in nearly every case. On the whole, heating also reduced the corrosion-resistance of the painted, chromate-treated blocks. On painted, untreated material, heating gave an improvement in the corrosion-resistance of each material, indicating that heat improved the paint. Bath iii) of D.T.D. 911, i.e., the hot, ½-hr. bath, gave better protection than either of the cold baths to all three alloys, both heated and unheated. The intrinsic corrosion-resistance of untreated D.T.D. 285 was greater than that of D.T.D. 281, which in turn was greater than that of D.T.D. 136A. After heating, however, the corrosion-resistance of all three materials was equal to that of D.T.D. 285 unheated. Full details of the corrosion test used and of the corrosion produced in each case are included.—MA.

5.4, 3.3, 6.4

Tests on Phenyl Mercury Acetate as a Fungicide in Paints for the Protection of Magnesium Alloys. H. G. Cole. Selected (Brit.) Govt. Research Rep., Vol. II.—Paints, Rep. **1949,** No. 7, 63-70.

Magnesium alloy strip to D.T.D. 259 was used in the tests and painted with both a mat black cellulose finish and a mat black synthetic finish applied over an oil/resin primer heavily pigmented with zinc chromate. The finishing paints were also used with an addition of 1 part in 2000 of phenyl mercury acetate. Mould-growth tests were made, and it was shown that the fungicide did not entirely stop mould growth during a month's incubation at 30° C and 100% relative humidity. The fungicide did not affect the protection given to the magnesium alloy as judged by a sea-water spray test. In the absence of free water, the painted alloy did not corrode when kept for 4 months at room temp. in proximity to green oak and green spruce, although considerable blistering of the paint occurred. The presence of fungicide did not appreciably alter the behavior of the paints. Unpainted specimens were heavily corroded in the presence of green oak and slightly corroded in the presence of green spruce.—MA.

5.4, 6.4

Protective Films; Natural Formation on Aluminum and Its Alloys. F. A. Champion, British Aluminum Co., Ltd., Chalfont Park, Eng. *Corrosion,* **5,** 92-97 (1949) Mar.

The protective oxide film which forms on aluminum and its alloys in air or other corrosive environments controls the form of a corrosion-time curve. This curve generally follows an exponential law except 1) during the initial growth period (about 2 hr. at normal temperature) during which the growth is logarithmic, 2) under severe conditions, when the solubility of the oxide is so high that film formation is impossible, and 3) when oxidative corrosion is accelerated by stress resulting from free loading. By ignoring these exceptions, the corrosion-time curve can be extrapolated from results obtained within a relatively short time, provided specimens are withdrawn at suitable intervals. This method of determining corrosion resistance is generally a more reliable method of expediting results than is an artificial acceleration of the actual corrosion process.

Corrosion observed in the early stages of exposure under severe conditions may give an unduly pessimistic impression sion of the useful life of aluminum alloys unless the decrease and eventual cessation of corrosion is borne in mind. Exposure of test specimens for a single arbitrary period is of little use for predicting behaviour in service.

Corrosion-time curves of pure aluminum were studied by a gasometric method. The specimens were machined, annealed, degreased, and totally immersed in a horizontal position in 1 N potassium chloride at a pH of about 5.5 under 1 atm purified oxygen. Total corrosion was calculated periodically from the amounts of hydrogen evolved and of oxygen absorbed. The former, which accounted for 35-40% of the total corrosion, could be accurately measured throughout each experiment, whereas accurate determination of the latter was sometimes impossible, especially on prolonged exposure.

PDC Comment: The growth and properties of natural oxide films are also described in two papers by Fred Keller and Junius D. Edwards: 1) Composition and Properties of the Natural Oxide Film on Aluminum. *Metal Progress,* **54,** 195-200 (1948). PDA 6: Met 144, G-3200, 2) Formation of the Natural Oxide Film on Aluminum. *Ibid.,* **54,** 35-41 (1948). PDA 6: Met 178, G-3169.—PDA.

5.4

Drying Oils and Resins. H. Dannenberg, T. F. Bradley, and T. W. Evans. *Ind. and Eng. Chem.,* **41,** No. 8, 1709-1711 (1949).

Oxygen-convertible alkyd resins with excellent properties have been synthesized from petroleum. Surface coatings made from the polyesters have outstanding properties in applications where elevated temp. can be used for forced drying or baking of the films. Coatings were made on glass, wood, steel, tin, aluminum, and copper without difficulty and the adherence of the coatings to their backings was always satisfactory. The results obtained are briefly discussed.—M.

5.4, 2.1

Testing Organic Finishes. *Die Castings,* **7,** No. 11. 43-46 (1949) Nov.

Discussion of methods developed for the evaluation of organic coatings includes preparation of test pieces, adhesion tests, impact tests, distensibility and accelerated tests. Salt fog chambers, humidity rooms and cabinets, and weathering machines are well known examples of the accelerated type of tests. Suggestion for an exposure cabinet is one constructed of Monel with a water jacket around the four sides. In salt fog chambers, Monel is described as a satisfactory container for a neutral salt solution that is properly adjusted.—INCO.

• Surface Treatment

5.9, 5.4

A Pretreatment Primer—Another Approach to Paint Adhesion. *Ind. Finishing,* Lond., **1949,** 698-699, June.

The advantages and methods of use of a proprietary pretreatment primer which combines a pretreatment etch or pickle with the deposition of a zinc-chromate-rich corrosion-inhibiting film are described. It is suitable for use on aluminum, aluminum-rich alloys, iron, steel, zinc, galvanized iron, tinplate and copper, brass and cadmium plating. After application, the primer becomes completely stable, and may be followed by any conventional organic type of finish, including cellulose, synthetic-resin-based products, oil-based finishes, or stove-type enamels which cure at a max. temp. of 250° F (121° C) by convection or infra-red radiation.—MA.

5.9

Phosphate Coating and Finishing of Tracy Kitchen Cabinets. *Ind. Heating,* **16,** No. 12, 2202-2204+ (1949) Dec.

Mild steel parts are subjected to a spray impingement of Duridine, a mildly acidic phosphate coating and cleaning chemical. Paint when applied flows

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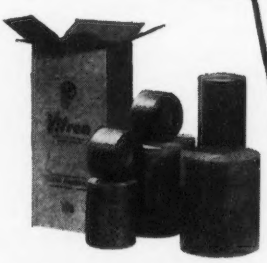

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33a

around the uniformly structured crystals and is anchored there on drying. The Duridizing process is described. Two coats of paint are applied over the phosphate coating to all exterior and interior surfaces. The cleaning, coating and finishing operations are described.—INCO.

5.9

An Electrolytic (Copper) Wire Cleaner. C. B. Leape. *Organic Finishing,* **10,** No. 11, 12-13 (1949) Nov.

Brief description with diagram of a cleaner which has been installed at the Westinghouse Electric Corporation. The dirty Cu wire passes over a pulley through a negatively charged perforated structure into the electrolyte which is an alkaline solution containing a wetting agent. This solution, which also serves as a degreaser, is continuously circulated by a pump and heated by a heat exchanger. This cleaning pretreatment improved the quality of enameled wire. —BNF.

5.9, 6.4

The Importance of Chemical Buffering in the Treatment of Magnesium Alloys. L. F. Le Brocq and H. G. Cole. *Metaux et Corrosion,* **24,** Nos. 287-288, 177-191 (1949).

The commercial usefulness of baths for the chromate treatment of magnesium alloys depends to a large extent on their ability to maintain a constant pH; if the pH rises during use, the bath becomes inoperative until the pH is brought back to the correct level by the addition of acid. LeB. and C. studied the buffering of numerous chromate baths by making stepwise additions of magnesia, potassium hydroxide, or ammonium hydroxide and following the changes in pH. Particular attention was directed to the bath (iii) of specification D.T.D. 911A. This bath, which is used boiling, was found to be well buffered, the buffering being due partly to the conversion of dichromate ions to chromate ions and mainly to the tendency for ammonia to be boiled off during use. The buffering of cold baths was also studied, and a number of possible buffering agents was investigated. Cold chromate baths, which should operate at about pH 4, can be satisfactorily buffered by addition of potassium alum. The reactions occurring in baths of this type (including bath [ii] of D.T.D. 911A) were examined in detail. Other buffering agents showing promise were phthalic acid, propionic acid, succinic acid, and selenious acid. The buffering powers of a number of commercially used baths were determined. The following were found to be well buffered: 1) all the baths (i)-(iii) of D.T.D. 911A; 2) baths containing transitional element sulphates; 3) strongly alkaline anodic baths; and 4) strongly acid chromate dips. The following baths were unbuffered or poorly buffered: 1) baths containing alkali persulphate, 2) baths containing alkaline earth sulphates and 3) anodic baths containing phosphates.—MA.

5.9, 5.4, 6.4

Preparation of Aluminum for Painting. R. Mansell. *Aero Digest,* **57,** No. 4, 46-7 (1948). *Chem. Abs.,* **43,** No. 18, 7237f (1949).

Various treatments such as chromatizing and phosphatizing are reviewed. Al can be used sometimes without finish or protective coats, owing to the natural formation of a transparent, inert, oxide film on its surface. Protective coatings must be applied if there is a possibility that the oxide film may be attacked by a corrosive environment.—RPI.

5.9, 5.3

Surface Preparation for Metallizing. R. Mansell. *Steel Processing,* 241-4+ (1949) May.

A description of methods used for preparing surfaces for metal spraying. Mechanical and blasting methods are only briefly reviewed, but more space is devoted to describing electrical bonding methods. In these a nickel electrode is moved over the metal giving it a roughened crater-like surface. In the Fusebond process, the electrode metal is exploded into a foam which adheres to the underlying metal in irregular patches. The Sprabond process eliminates the necessity for any surface preparation other than cleaning, since, it is claimed, the special metal used adheres firmly to smooth surfaces.—ZDA.

5.9

Sodium Silicates in Metal Cleaning. Clinton W. MacMullen and Clarence G. Ozar, Cowles Chemical Co., Cleveland. *Metal Fin.,* **47,** No. 4, 52-54 (1949) Apr.

Sodium silicates possess a high detergent potential and their use in the metal cleaning field is steadily expanding. Approximately 75 percent of the proprietary alkaline metal cleaners on the market contain silicates. The following advantages are cited:

1) The action of silicate solutions approaches that of true colloidal electrolytes, i.e., by dissociating hydrolytically to produce colloidal agglomerates or micelles. The silicates tend to stabilize emulsions, increase deflocculation, and lower surface and interfacial tensions.
2) In the majority of alkaline cleaning processes for metal, little is accomplished below a pH of 10. Silicates tend to resist pH change and offer more active alkalinity than do the other common alkalies, except sodium hydroxide which has a low detergent potential.
3) Silicates act as corrosion inhibitors in metal cleaners compounded for the more active metals, especially aluminum. They are the only economical alkaline products which clean and inhibit at the same time.
4) Silicates are considered particularly effective as rinsers because of their superior emulsifying and colloidal properties and their tendency to prevent redeposition of dirt.

Zinc and zinc-base die castings can be successfully cleaned in sodium metasilicate solutions, good results depending upon the choice of the proper ratio of Na_2O/SiO in the silicate. Sodium metasilicate and sesquisilicate can be used advantageously in 3 percent solutions at 195 degrees F with a current density of 1 amp per sq dm for anodic (reverse) cleaning. Under the same conditions di- and trisilicates give heavy white deposits on the anode. Cathodic (direct) electrocleaning may be carried out over a much wider range of concentration, temperature, and current density.

5.9, 6.4

Increasing the Corrosion Resistance of Phosphate Films by Subsequent Treatment with Pore-Filling Materials. (In German.) W. Machu. *Archiv fur Metallkunde,* **3,** 335-340 (1949) Oct.

Filling the pores of phosphate films on Al and Al alloys with insoluble inorganic compounds reduces the porosity of such films by about 50 percent. While the addition of inhibitors increases rather than decreases porosity, their use is recommended, since they improve corrosion resistance. Effects of different inorganic compounds were comparatively evaluated. Includes tabulated data.—BLR.

5.9, 6.4

Pretreatment of Aluminum Sheet for Painting. G. W. Birdsall. *Metal Prog.,* **56,** 825-828 (1949) Dec.

Describes properties and procedures of application used by Reynolds Metals Co. In processing the sheet, an extremely thin layer of the base metal is dissolved to form the aluminum phosphates and other compounds that make up the coating.—BLR.

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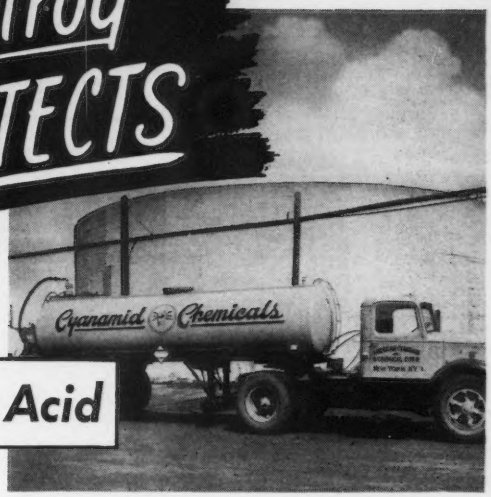
Wright Chemical Corp.	8

Where Acids Destroy PRUFCOAT PROTECTS



. . . Sulphuric Acid

The plant that manufactured the acid in this tank truck is protected with Prufcoat, as are dozens of other sulphuric acid manufacturing plants throughout the country. (Names of these plants on request.)

Yes, in plants which actually manufacture sulphuric acid—*the "oil of vitriol" that dehydrates, digests and destroys* —as well as in plants producing other mineral acids, organic acids and alkalies, Prufcoat Protective Coatings have been providing positive protection against costly corrosion for over ten years now . . . *on concrete floors, walls, ceilings, structural steel, pipes, tanks, ducts, machinery and equipment.* Performance records in these chemical manufacturing plants, and in the process industries using their highly corrosive products, *prove* that where acids or alkalies destroy, *Prufcoat Protects.*

Coat for Coat, Prufcoat Gives More Protection at Lower Cost Than Any Other Air-drying Paint

Economical in original cost as well as in the preventive maintenance terms of positive protection against costly corrosion, Prufcoat Protective Coatings come ready-to-use in single, five and 55 gallon containers and are available in a wide range of attractive colors including green, buff, black, red, white, and several shades of gray.

An experienced Prufcoat corrosion engineer will gladly make a Preventive Maintenance Survey of *your* plant. No obligation, of course. *Write today, describing YOUR corrosion problems.*

NEW!

Prufcoat Metal-Reactive Primer P-10

Does not require as complete surface cleaning as most other priming methods and works well on damp or dry surfaces. Makes possible a simple yet positive two-step system for corrosion-proofing old or moist metal surfaces. Write today for Prufcoat Technical Bulletin 012.

See us at Booth 81 at the NACE Exhibit, March 13-16, Statler Hotel, New York City

Preventive Maintenance PAYS

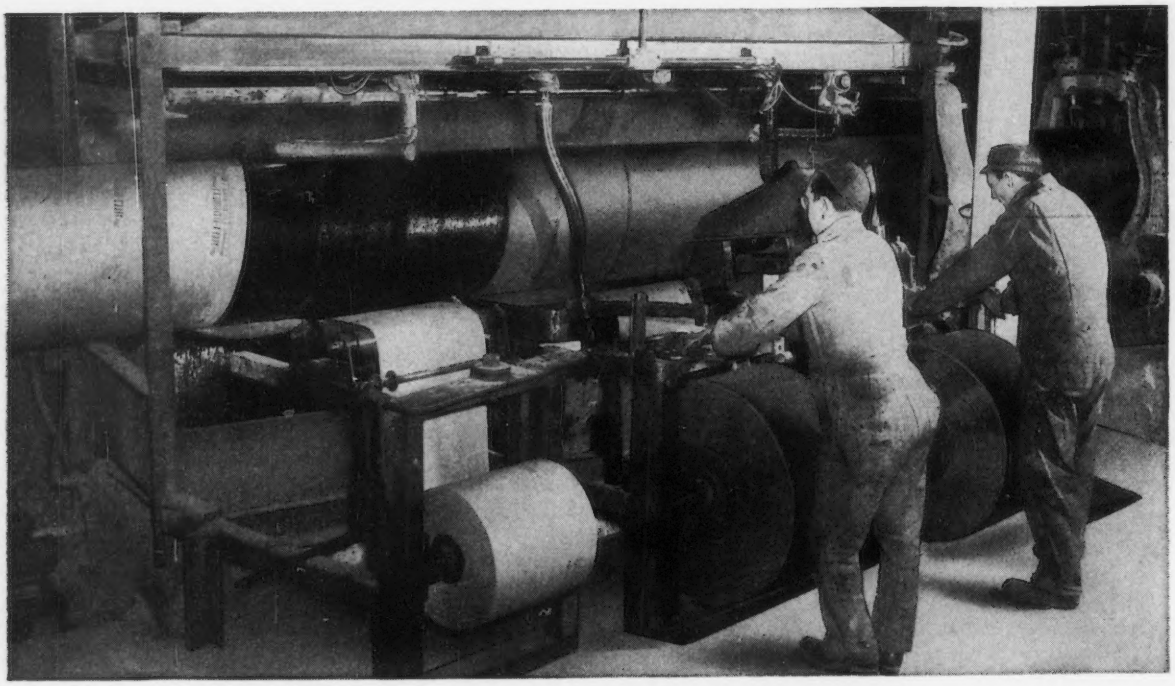
PRUFCOAT LABORATORIES, INC.
50 East 42nd Street, New York City

35a

How to cut your pipe-protection costs:

Ask today's corrosion engineers. They'll tell you where the *major* cost of a pipe-protection job too often lies. It comes in the heavy *maintenance* expense. They've learned that with *all* pipe—from distribution mains and service pipe to long transmission lines—costs must be measured in *years of trouble-free service.*

That is why they check into *every stage* of a protection process before placing a job. For only when each vital step is skillfully *controlled* can pipe resist every agent of corrosion.



THIS PICTURE SHOWS how Hill, Hubbell's heavy-duty equipment applies any standard specification of coating and wrapping. All operations, regardless of number or type of layer, are done *simultaneously*. Only this factory method can guarantee positive, uniform bonding—so essential to *lasting* resistance against corrosion.

This modern, efficient machine and its skilled operators are indicative of how Hill, Hubbell controls *every* stage of pipe conditioning and application. It helps explain why so many corrosion engineers insist on Hill, Hubbell-protected pipe for the *long-range* service that keeps protection costs low.

"March to New York"
DROP IN AND SAY HELLO..Booth No. 104-105
—Milt Bowan and staff

Hill, Hubbell and Company
Division of GENERAL PAINT CORPORATION

Headquarters: 3091 Mayfield Road, Cleveland 18, Ohio

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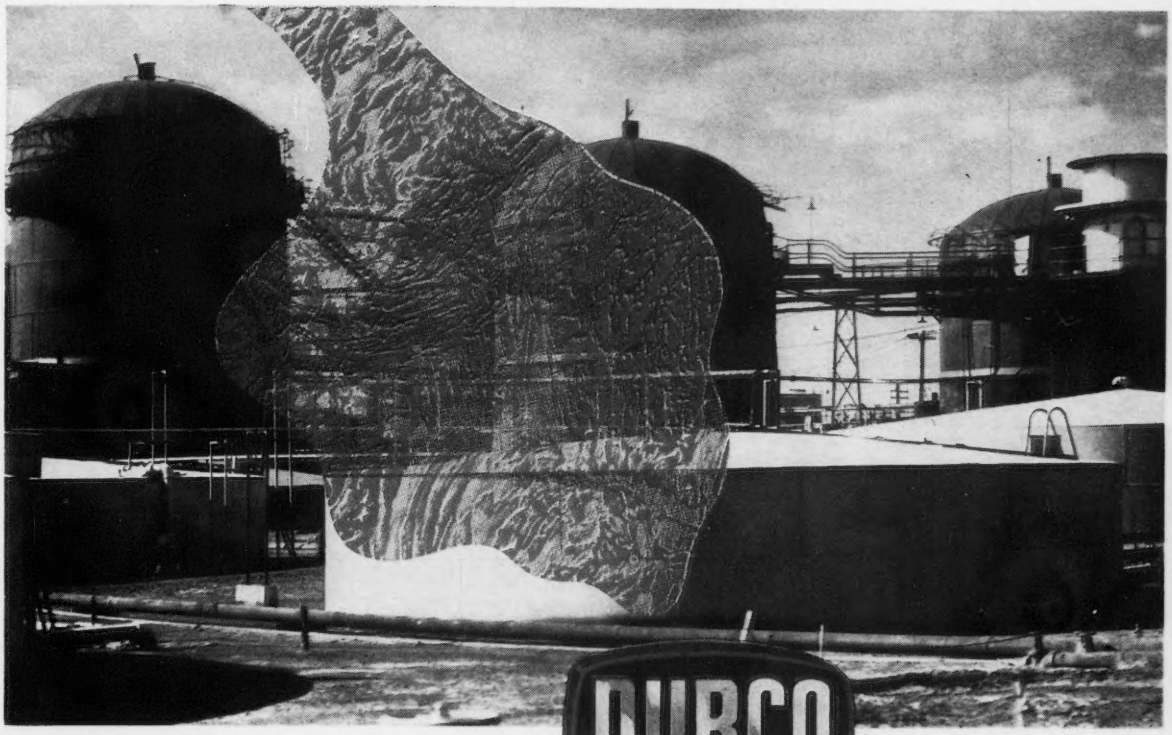
where corrosion hits hardest...



a team of DURCO CORROSION RESISTING ALLOYS & EQUIPMENT alloys fights it to a standstill

Why does industry consistently come to The Duriron Company with its toughest corrosion problems? A major reason is the wide range of alloys in which DURCO equipment is supplied. DURCO equipment is made in as many as 8 standard alloys... and our foundry produces more than 20 different compositions every month.

Why so many?

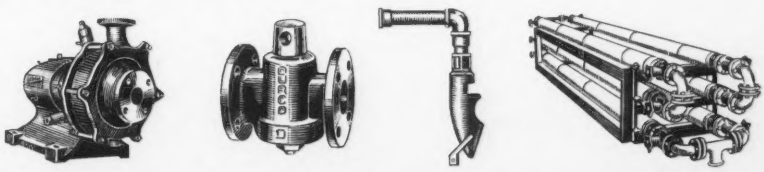
Because the destructive effects of corrosive agents used by industry vary with the agents themselves and with the conditions under which they are used. To be fully effective, the alloy must *fit* the prevailing conditions as well as the corrosive material.

In grappling with corrosive problems for nearly 40 years, DURCO has developed the largest team of alloys ever produced by a single company. That team is always available to industry, together with the technical experience that produced it.

Write, wire or call for information.

The Duriron Company, Inc., Dayton, Ohio

DURCO CORROSION RESISTING ALLOYS & EQUIPMENT



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